THE FALLOUT OF NITROGEN AND PHOSPHORUS COMPOUNDS FROM THE ATMOSPHERE AT NGAPUNA, NEAR ROTORUA, NEW ZEALAND

G. R. Fish*

ABSTRACT

A total of 183 samples of atmospheric fallout, usually collected over periods of 24 hours (never longer than 3 days) between April 1974 and April 1975 was analysed for N and P content. Local bush fires and pollen-fall caused some changes in fallout quality but seasonal effects were generally slight. Dry fallout contributed 0.37 g/ha.day PO_4-P and 0.77 g/ha.day total P (36 and 54 percent of the deposition on raindays), whilst the nitrogen contribution was 1.03 g/ha.day NH_4-N and 0.24 g/ha.day NO_3-N (10 and 7 percent of the rainday deposition). The data are compared to those collected previously on rainfall only and used to improve the estimate of the atmospheric contribution to the nutrient budget of Lake Rotorua.

INTRODUCTION

The levels of dissolved nitrogen and phosphorus compounds in the water of several rainstorms monitored at Ngapuna, Rotorua, have been reported (Fish, 1976). The investigation was extended for a further year (April 1974–75) and the data reported here show the fallout of these compounds over periods of time. It is well known that such fallout continues in the absence of rainfall, but the amounts vary greatly and few data have been published for New Zealand.

METHODS

A V-shaped trough (horizontal opening 0.47 m^2) made of plate glass was used as a collector in the present study. All seams were at right angles and secured with a chemically inert cement (RTV 732). The collector had been used for rainwater collections for some years previously and so the apparatus was well leached. However, whenever the collector and reservoir surfaces were cleaned, the final

* Fisheries Research Division, Ministry of Agriculture and Fisheries, Rotorua.

distilled water rinsing was continued until the washings contained no detectable N or P solutes. The apparatus was supported a metre above the roof of our single-storied research laboratory at Ngapuna and no trees or higher buildings were nearby. Clearly, wind across the collector opening would affect the efficiency of sample collection but, in the present study, this effect was neglected because a reliable straight-line relationship was found between the amounts of rainwater recovered from the reservoir and those measured in adjacent, standard raingauges. We were probably fortunate in that windspeeds at Rotorua are amongst the lowest in New Zealand.

Between 8 April 1974 and 3 April 1975, 183 samples were collected. Sampling was of 24-hour duration as often as possible but no sampling period was longer than three days. When longer periods elapsed between sampling, the collector was covered and its surfaces thoroughly cleaned before further use. If rain fell during the day, the water collected was deemed to carry all the atmospheric fallout material. On a dry day, the collecting surfaces were washed with distilled water until 500 ml had accumulated in the reservoir. Polycarbonate sample bottles were used and, unless analysis was made on the day of collection, samples were stored below 0°C.

The water samples were analysed for reactive phosphorus (designated here as PO_4-P), nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N) and total phosphorus (total P) using methods described by Fish (1976). Sometimes insoluble matter was clearly present in the samples. It was decided that settleable solids would not be analysed and so all samples were mixed, allowed to stand for 30 minutes, and then decanted before analysis.

The results were calculated on the basis of amounts precipitated in g/ha.day, for the investigation was primarily designed to estimate the rates of dry fallout, rainfall precipitation having been examined previously (Fish, 1976). If any rain fell during the sampling periods, the solutes in the sample were considered to be the precipitation on a 'rainday'. Such samples contained components of both wet and dry precipitation. Printouts of the data collected will be provided by the author on request.

RESULTS

Table 1 gives the means of total, rain and dry fallout at Ngapuna over the year of study. It is likely that most of the solutes measured were carried in rainfall, since the mean daily fall on dry days of NH_4-N was only about 10 percent of that on wet days, and of NO_3-N was about 7 percent. The corresponding proportions of PO_4-P and total P were 36 and 54 percent respectively, which sug-

TABLE 1 — The mean of all observations made on the natural fallout at Ngapuna, Rotorua, between April 1974 and April 1975.

	PO_4-P (g/ha.d)	NH_4-N (g/ha.d)	NO_3-N (g/ha.d)	Total P (g/ha.d)	Rainfall (mm/day)
No. of observations:	183	183	183	107	183
Maximum:	18.72	103.48	23.40	9.19	113.2
Minimum:	0.03	0.10	0.01	0.08	0.2
Mean:	0.74	6.26	1.96	1.12	7.71
Standard error:	0.14	0.87	0.23	0.14	1.12
Raindays only					
No. of observations:	104	104	104	57	104
Maximum:	18.72	103.48	23.40	9.19	113.2
Minimum.	0.03	0.20	0.05	0.11	0.2
Mean:	1.03	10.70	3.26	1.42	13. 58
Standard error:	0.18	1.56	0.32	0.20	1.48
Dry days only					
No. of observations:	79	79	79	50	79
Maximum:	1.91	8.51	0.59	8.51	0
Minimum:	0.04	0.10	0.01	0.08	0
Mean:	0.37	1.03	0.24	0.77	0
Standard error:	0.16	2.77	0.29	0.17	–

TABLE 2 — A one-way analysis of covariance in precipitation between the mean daily amount of some N and P solutes (in g/ha.day on the Y axis) and the amount of rainfall (in mm/day on the X axis). The coefficient has a significance better than 0.1 percent in each case.

Regression	Coefficient	Variance ratio (F)	Intercept
PO_4-P : Rain	0.5719	88.00	0.257
NH_4-N : Rain	0.4714	51.71	3.277
NO_3-N : Rain	0.6873	162.02	0.817

gests that their deposition is comparatively independent of rainfall. On 28 dry days, measurable amounts of dew or frost were precipitated (maximum 0.40 mm, minimum 0.04 mm, mean 0.13 mm) but without discernable effect on the fallout of N and P components.

Table 2 gives the analyses of variance between rainfall and the associated fallout on raindays of inorganic N and P. A direct relationship was found in each case. The value of the intercept of PO_4-P at zero rainfall is of the same order as that measured on dry days, which suggests that the relationship between P fallout and rainfall is fairly linear. The values for the intercepts of the N species at zero rainfall are much higher than those of the measurements of dry fallout, and probably the relationship between these parameters and rainfall is more complex.

Figs. 1 and 2 give the mean monthly fallout rates as derived from simple calculation of the raw data on raindays and dry days.

The rainday fallout of PO_4-P shows a clear relationship with rainfall and neither parameter appears to show any seasonal variation. The same is likely to be true for the fallout of NO_3-N, but higher rates of rainday fallout of NH_4-N occurred in the summer compared to the winter season. This seasonality is probably the reason for the relatively small coefficient found in the regression between NH_4-N and rain (Table 2) compared to those for the other two solutes. On dry days, the greatest rates of PO_4-P and NH_4-N were found in the early winter, and that for NO_3-N was found in late summer. The differences are not large, though, and it is unlikely that the fluctuations in dry fallout rates showed any seasonal trend.

Sources of the N and P were rarely evident during this study. Although the projecting glass edges of the collector provided unsatisfactory perches for birds, on two occasions it was suspected that bird droppings had contaminated the samples. When analysed, the PO_4-P and NH_4-N concentrations were about 10 times greater than those normally found but the NO_3-N concentrations were not unusual. Although birds did not roost on the collector, the droppings

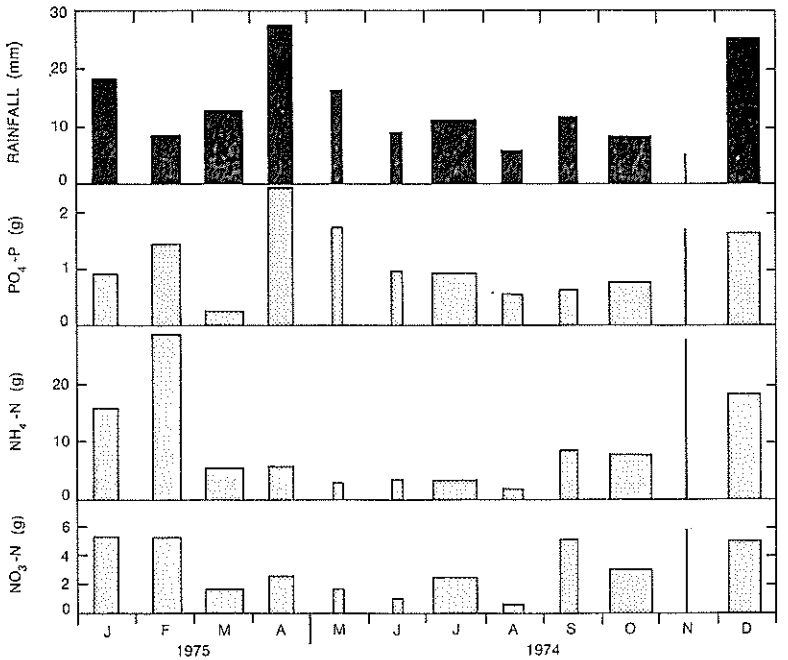

FIG. 1 — The mean monthly precipitation rates on raindays of rain (mm) and of N and P solutes (g/ha.day) at Ngapuna, Rotorua. The number of observations in each month is indicated by the widths of the vertical columns.

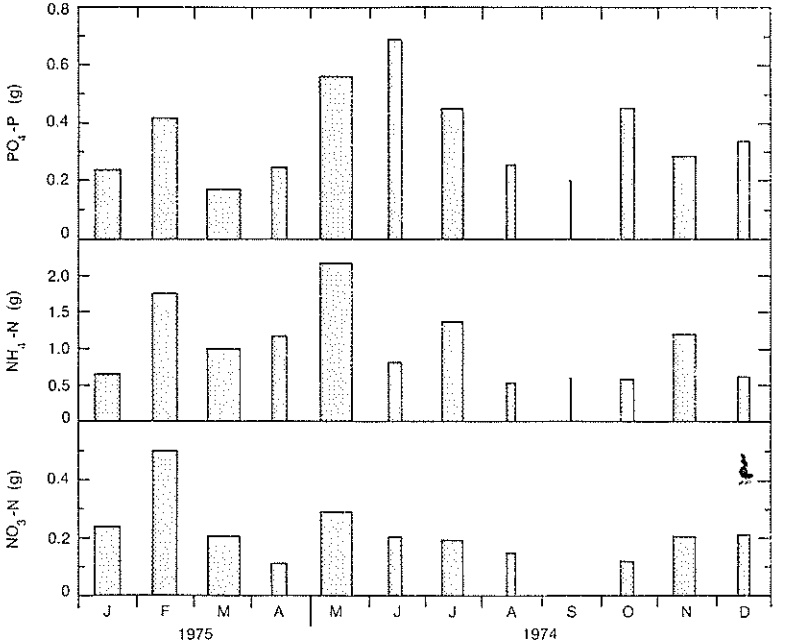

FIG. 2 — The mean monthly precipitation rates on dry days of N and P solutes (g/ha.day) at Ngapuna, Rotorua. The number of observations in each month is indicated by the widths of the vertical columns.

of roosting or flying birds should perhaps be considered a legitimate fraction of atmospheric fallout. However, the contamination was too localized for inclusion in these results.

On the other hand, material that could have been received from nearby aerial topdressing or from fires was included. On one occasion, topdressing activities were seen on nearby farm land about a kilometre away. Subsequent samples, however, were not obviously enriched. On three occasions, local bush fires darkened the sky overhead and flecks of ash were found in the water samples. On one of these occasions (1 May 1974), the fire was a controlled operation involving about 140 ha of bush at Taheke, 25–30 km northwards. There was a light (up to 3 m/s) north-to-northwest wind during the day, and the insoluble ash collected at Ngapuna amounted to over 1.5 kg/ha.day. The samples collected next morning contained increased PO_4-P (1.6 g/ha.day) and total P (8.5 g/ha.day) concentrations but little change was found in those of NH_4-N and NO_3-N.

During the late winter, the large conifer forests near Rotorua release copious amounts of wind-borne pollen, and on five occasions during August 1974 pollen was visible in the samples. The pollen made no significant contribution to the N and P solutes present but enhanced the total P concentrations. On 7 August 1974, when pollen was evident in the daily sample, the solids present amounted to 1.7 kg/ha.day, and although no rain had fallen during the 24-hour period, the total P in the atmospheric fallout amounted to 1.27 g/ha.day. Probably about half the particulate matter in the sample was pollen, for Nielsen *et al.* (1955) showed that *Pinus montana* pollen usually contained 0.3 percent P.

DISCUSSION

The fallout of P solutes from the atmosphere at Ngapuna was of a similar order to that found in studies elsewhere. For example, both Owens (1970) who reviewed data from Britain, and Stewart and Markello (1974) in western New York found atmospheric fallout of total P to be within the range of 0.5 to 2.7 g/ha.day and of inorganic N to be within 22.4 to 52.1 g/ha.day. The fallout of N solutes at Ngapuna seems to be comparatively low, especially that of NO_3-N. Likens (1972) found the mean rain fallout of N solutes at Aurora, New York, to be 22 g/ha.day of NO_3-N and 9 g/ha.day of NH_4-N. He examined previous records of rainfall analysis for the area and found that progressive changes had occurred over the last 30 years, with the nitrate component becoming much larger, and the ammonium changing little. He suggested that increasing development, especially in the use of fuels such as petrol, may account for the increasing amounts of NO_3-N in precipitation.

The daily dry fallout of N and P at Ngapuna is likely to be less than half that deposited on raindays but Chapin and Uttormark (1973), in their review of world literature, note that most authors have found that dry fallout contains much greater amounts of these elements than is found in rainfall. The reviewers also found that many authors report a pronounced summer maximum of N and P solutes, especially of total P, in fallout and suggest the cause may have been increased suspension of terrestrial dust during warm, dry weather. However, little evidence of such marked seasonality was found in the present study, possibly because of the typically non-seasonal distribution of rainfall during 1975 at Rotorua.

Atmospheric sources of N and P are probably insignificant in terms of agricultural fertilization, but limnologists often find these

increments are important in lake inflow budgets. Chapin and Uttormark (1973) quote N loadings from atmospheric sources of 27 g/ha.day and show that such increments to shallow lakes may even be sufficient to cause eutrophication problems. This is understandable, for in rural Blacksburg, Virginia, Parker and Wodehouse (1970) have quoted figures for rainfall that reached 1.39 kg/ha.day of inorganic N on two occasions during July 1970.

Rainfall on the surface of Lake Rotorua, a large, shallow lake in the North Island, has been shown to be its largest water source (Fish, 1975). Relatively few rainwater analyses were available at the time when the lake's nutrient budget was estimated, and the present work is useful in providing better data on rain and dry fallout as a nutrient source. Corrected estimates indicate that atmospheric fallout over the survey period between 1967 and 1970 probably contributed 5.2 kg/day of PO_4-P, 40.0 kg/day of NH_4-N and 11.8 kg/day of NO_3-N to the mean nutrient inflow of Lake Rotorua. These increments represented 5.5 percent of the total PO_4-P income, 2.7 percent of the NO_3-N and 19.4 percent of the total NH_4-N income to the lake.

Progress in measurements of N and P fallout is probably better directed towards measurements at several stations rather than further surveys at our single station in Rotorua. There seems to be good evidence now that, firstly, dry fallout provides only the lesser proportion of the total atmospheric fallout, including rainfall of N and P (see Table 1) and secondly, that the concentration of N and P solutes in rainwater is likely to be fairly constant over annual periods at the single station. Analyses of many rainfall samples (strictly excluding dry fallout) over 1972–74 showed the mean concentration to be 6 mg PO_4-P, 84 mg NH_4-N and 22 mg NO_3-N per m^3 (Fish, 1976). The present data yield a mean rainfall concentration over 1975 of 7 mg PO_4-P, 78 mg NH_4-N and 24 mg NO_3-N per m^3. This close similarity is supported by Table 2, which shows that a highly significant, direct relationship existed between N and P solutes and rainfall amounts over 1975. It would be of considerable interest to determine whether these two aspects of fallout in Rotorua are characteristics also of fallout elsewhere in New Zealand.

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