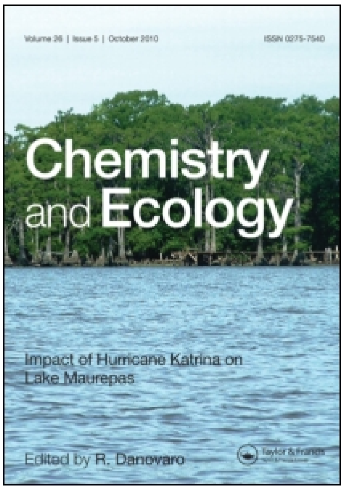

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INPUT, UPTAKE AND THROUGHPUT OF POTASSIUM IN A SMALL CHALK STREAM, THE BERE STREAM (DORSET)

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Inputs of potassium from rainfall, throughflow from trees, input from groundwater and input from watercress beds to Bere Stream, a small chalk stream, have been measured. Inputs from rainfall and canopy were negligible compared to the inputs from groundwater and the influence of fertilisers added to watercress beds. The natural plant population removed only a small proportion of the overall throughput of potassium in solution (<3%).

KEY WORDS Potassium, input/output, fertilisers, Bere Stream

INTRODUCTION

In most natural waters the concentration of potassium is much lower than that of sodium. Concentrations of potassium are usually in the range 0–5 mg l^{-1}. This narrow range of concentrations suggests that a significant control mechanism is involved (Hem, 1970). However, Casey and Farr (1982) found that increases in potassium levels could result from increased discharges in the absence of allochthonous inputs during artificial spates. The peaks found suggested a release of potassium from within the stream, either from sediment/water exchange mechanisms or possibly release of potassium from decaying plant material.

Potassium is an essential plant nutrient and many chalk stream aquatic plants contain high levels of potassium compared to sodium and calcium concentrations (Casey and Downing, 1976). Previous work has also shown that when aquatic plant growth is at its maximum, potassium concentrations in some chalk streams can reach very low levels (Casey and Westlake, 1974).

STUDY AREA

The Bere Stream is a small chalk stream in southern England; the geology, general chemistry and ecosystem has been described previously (Westlake *et al.*, 1970). The discharge regime and seasonality in nitrate concentrations for years 1966–1986 has been described by Casey *et al.* (1990).

The stream originates from natural springs but a large proportion of its flow is made up of water flowing out of commercial watercress beds. In years of low flow the watercress beds can provide twice as much discharge as the natural source (Casey, 1981). In the catchment of the Bere Stream above the sampling site there are approximately 57,000 m^2 of watercress beds.

METHODS

Water samples were taken weekly (normally on a Monday) from the same site on the Bere Stream below Bere Regis, Dorset (National Grid Reference SY 858923). The samples were hand collected using acid-cleaned bottles and returned to the laboratory where they were filtered through pre-washed GF/C filters. Potassium was originally measured using an EEL 227 Flame Photometer but since 1970 measurements have been made using Atomic Absorption Spectroscopy with ionisation suppression.

Inputs of Potassium to the Study Area

The four major inputs of potassium are: (a) rainfall, (b) throughflow from trees and other vegetation, (c) input from the chalk groundwater, (d) application of fertilisers to watercress beds.

(a) *Rainfall.* Crisp (1970) found that the concentrations of potassium in rainfall varied between 0.1–1.7 mg l^{-1} with a mean value of 0.3 mg l^{-1}.

This mean value is similar to that found by Whitehead *et al.* (1990) (0.33 mg l^{-1}) in Wales but higher than that found by other authors (Likens *et al.*, 1970 (0.07 mg l^{-1}), Feller, 1977 (0.07 mg l^{-1}) and Reynolds, 1984 (0.08 mg l^{-1}).

The Bere Stream site is only 15 km from the English Channel so that the influence of sea water on the rainfall composition was calculated. Calculations on rainfall data over a three-year period (1978–1980) showed that chloride to sodium ratios were close to the 1:1.8 value found in sea water. If all the chloride input in the rain was due to sea water, the mean potassium concentration of the rainfall would have been 0.16 mg l^{-1}. Therefore the sea water influence on potassium concentrations in the rainfall is large.

(b) Input from the tree canopy measured in the Bere Stream head waters varied largely between different species, with an annual mean of 1425 mg m^{-2} a^{-1} for ash and 3130 mg m^{-2} a^{-1} from ivy. Hornung *et al.* (1990) found bulk precipitation to have a mean annual potassium concentration of 0.3 mg l^{-1}, oak canopy throughfall to have a mean value of 2.35 mg l^{-1}, Sitka spruce to have a throughfall of 1.45 mg l^{-1} and stemflow of 3.68 mg l^{-1}, and ground flora throughfall to have an annual mean value of 7.82 mg l^{-1}. Hornung *et al.* (1990) state that the potassium increase in the throughfall is mainly derived from canopy leaching.

Calculations for the Bere Stream catchment above the sampling point showed that the total input of potassium from tree canopy and rainfall for 40,000 m^2 of stream bed to be only 1.78 kg a^{-1} compared with the stream outflow of over 50 tonnes a^{-1}.

However, after very heavy rainfall, potassium values in the stream rose to high values (4.2 mg l^{-1}) associated with an increase in discharge. Part of this increase could be washout from watercress beds but samples taken from above the watercress beds also showed an increase in potassium concentrations (these were associated with an increase in phosphate concentrations) and this was due to a small amount of farm effluent entering the stream.

Hourly samples taken on the River Frome (Dorset) over some flood periods have shown that potassium values increase with rising discharge (Casey, unpublished).

(c) Potassium concentrations of groundwater samples gave a mean concentration of 0.87 ± 0.017 mg l^{-1} from 150 weekly samples. Results measured from groundwater inputs to watercress beds gave a mean value of 0.86 ± 0.014 mg l^{-1} potassium from over 150 samples.

(d) Crisp (1970) found that applications of potassium fertiliser to an experimental watercress bed to be 138 g m^{-2} a year (average potassium concentration of the fertiliser was 15.7% dry weight). There are approximately 57,000 m^2 of watercress beds in the Bere Stream catchment, therefore, taking the values found by Crisp (1970), 7866 kg a^{-1} of potassium fertilisers containing 1235 kg of potassium could be added to the catchment. Crisp also found that up to 87% of potassium added as fertilisers and in borehole water could be lost during the ten hours after application of potassium fertilisers and potassium concentrations in the outflow water can reach a maximum of 550 mg l^{-1}.

Under normal management practices when no fertilisers are added, the outflow water from the watercress beds has lower potassium concentrations than the inflow water. When the watercress is actively growing, outflow potassium concentrations can be <0.05 mg l^{-1} (Casey, 1981).

Because of these extreme variations in nutrient levels in watercress beds, the major firm growing watercress is now adding nutrients directly to the inflow water as a nutrient spray, which can be controlled to suit the growing conditions.

Thus the passage of groundwater through watercress beds can act as both a sink for potassium by plant uptake or a major input from added fertilisers.

Potassium Concentrations in Bere Stream

Figure 1 shows the mean (the vertical bars denote one standard error about the mean), maximum and minimum concentrations for each calendar week using a data set of weekly samples over the 20 year period from 1966–1986. Even though the mean weekly values show only small fluctuations there are large differences in the maximum and minimum values. The highest value found was over 5 mg l^{-1} in June and this would probably be due to watercress bed fertilising at this season.

Figure 2 shows the yearly mean (the vertical bars denote one standard error about the mean), maximum and minimum concentrations for the years using a weekly sampling data set over the period 1966–1986. Each year's mean will be prone to statistical sampling error as it is only estimated from the 52 (i.e. weekly) samples.

There is no significant difference between years and no trend. However, the minimum values are slightly lower over the period 1983–1986.

Discharge

Discharge values are available only for the period 1968–1982 and are shown in Table 1. As can be seen from this Table the range is small but average discharge has increased since the mid-1970's.

Potassium Loads

Table 2 shows the weekly maximum, minimum and mean weekly potassium load in tonnes per week for the period 1968–1982, whilst Figure 3 shows the yearly load for the same time period. There is an increase in potassium load for the years 1980–1982 but this is not due to increased potassium concentrations but to increased discharge. The lowest potassium found for any one week was 300 kg/week.

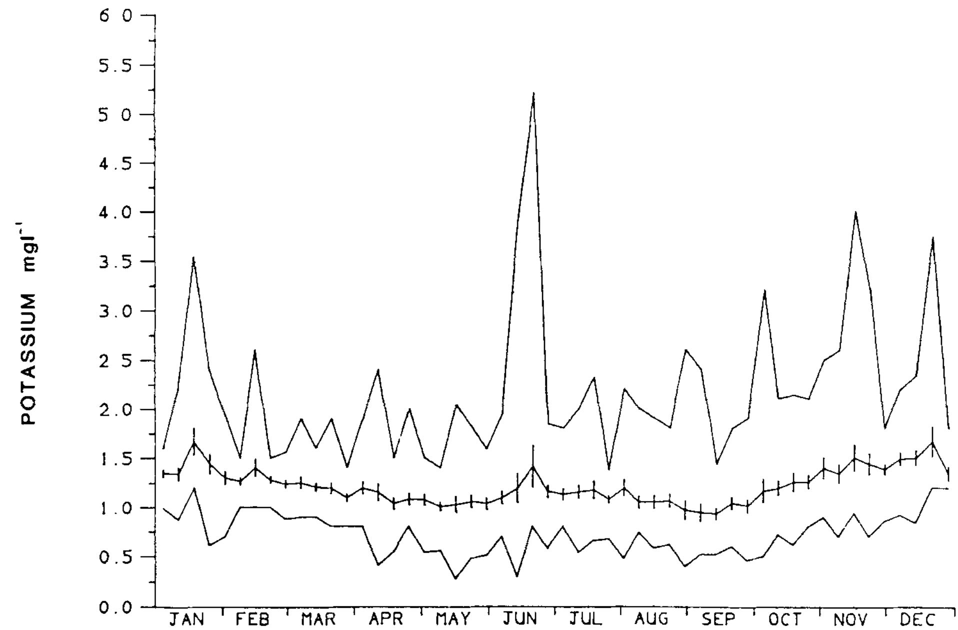

Figure 1 The mean (vertical bars denote one standard error about the mean), maximum and minimum potassium concentrations for each calendar week using a data set of 20 years from 1966–1986.

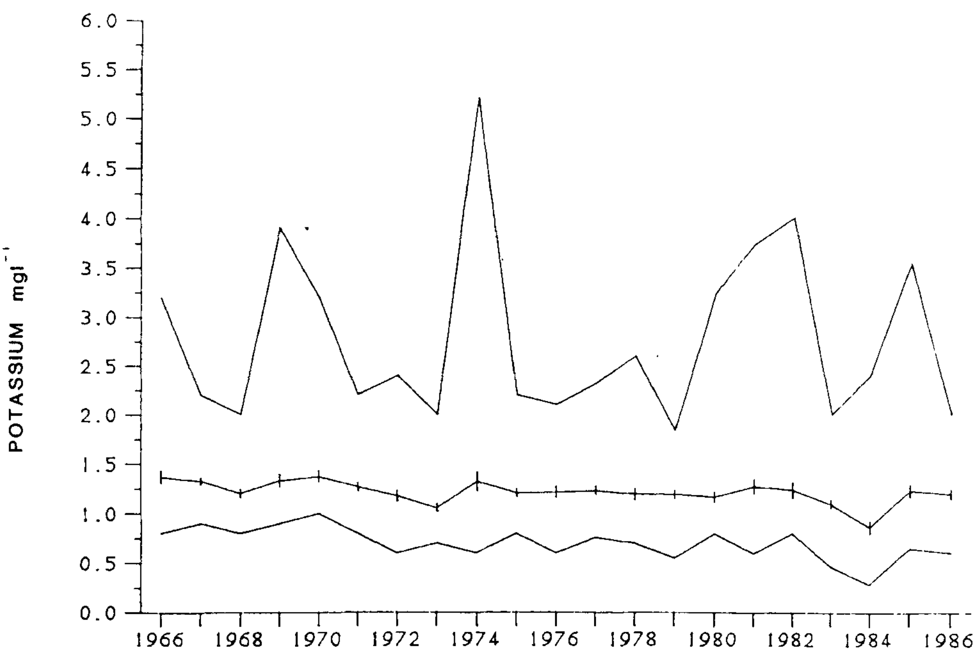

Figure 2 The yearly mean (vertical bars denote one standard error about the mean), maximum and minimum concentrations for the years 1966–1986.

Table 1 Bere Stream weekly mean discharge, 1968–1982, centred on chemistry sampling day, discharge (m^3s^{-1}).

Year	*Mean*	*S.E.*	*Min.*	*Max.*	*N*
1968	1.47	0.03	1.20	1.68	13
1969	1.17	0.05	0.72	2.02	52
1970	1.07	0.05	0.74	2.03	52
1971	1.12	0.04	0.87	1.65	26
1972	1.11	0.04	0.78	2.02	51
1973	1.00	0.04	0.67	1.67	52
1974	1.29	0.07	0.79	2.68	51
1975	1.21	0.06	0.82	2.32	52
1976	1.01	0.05	0.69	2.05	52
1977	1.38	0.06	0.90	2.33	52
1978	1.46	0.08	0.85	2.94	52
1979	1.44	0.06	0.97	2.19	48
1980	1.67	0.07	1.06	2.38	44
1981	1.87	0.06	1.32	2.38	35
1982	2.13	0.08	1.37	2.91	42

Table 2 Bere Stream potassium load (tonnes/week).

Year	*Mean*	*S.E.*	*Min.*	*Max.*	*N*
1968	1.30	0.09	0.80	2.03	13
1969	0.95	0.07	0.42	2.71	52
1970	0.91	0.06	0.45	2.21	52
1971	0.91	0.07	0.60	1.94	26
1972	0.80	0.06	0.30	1.96	50
1973	0.64	0.04	0.31	1.56	51
1974	1.03	0.09	0.30	2.96	50
1975	0.90	0.06	0.43	2.58	50
1976	0.78	0.07	0.28	2.08	50
1977	1.04	0.06	0.43	1.97	51
1978	1.06	0.08	0.45	2.77	46
1979	1.05	0.06	0.48	1.87	46
1980	1.22	0.09	0.51	4.00	43
1981	1.52	0.15	0.52	4.93	34
1982	1.60	0.11	0.79	4.48	39

Uptake of Potassium by the Plant Community in the Stream

Bere Stream has a plant community typical of a small chalk stream, with the community dominated by *Ranunculus* and *Rorippa* but many other species present in small numbers.

The pattern and production of plant growth has been described previously (Ladle and Casey, 1971). Production of *Ranunculus* varies from year to year with large differences, e.g. 96.8 g dry weight $m^{-2}a^{-1}$, to 350 g dry weight $m^{-2}a^{-1}$. The production of *Rorippa* is probably similar.

Chemical analysis of the plant material gave a potassium content of between 4.07–4.21% for *Ranunculus* (Casey and Downing, 1976) and 2.59% for the roots and 4.42% for the stems and leaves for *Rorippa* (Crisp, 1970). Thus the production of *Ranunculus* for 40,000 m^2 of stream bed could remove between 160–560 kg a^{-1} of potassium, and the *Rorippa* production could remove between 136–488 kg a^{-1}. The amount of potassium lost to total plant production has a maximum of 1048 kg a^{-1},

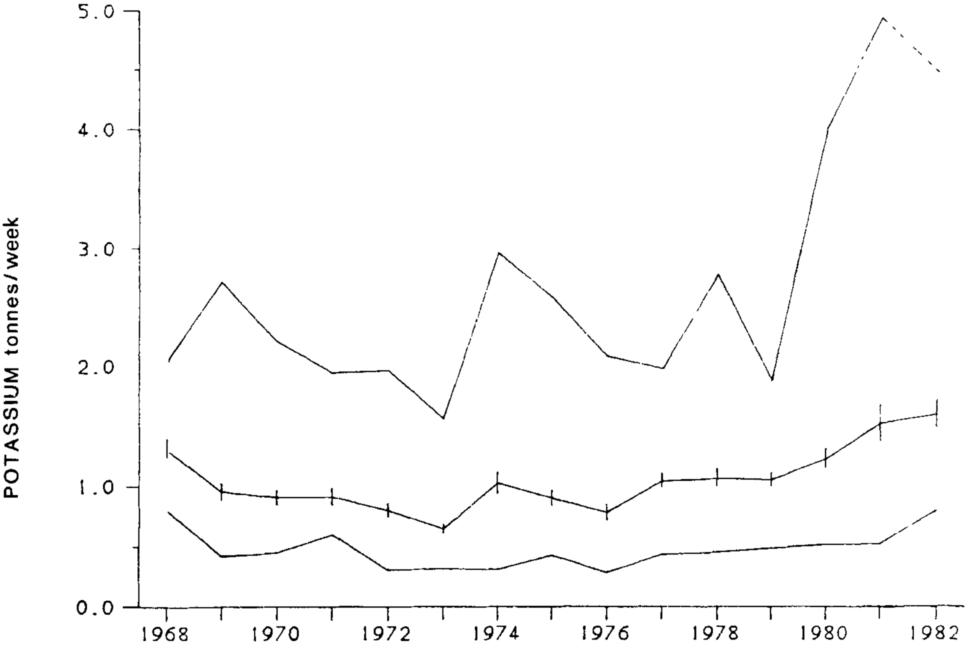

Figure 3 The mean (vertical bars denote one standard error about the mean), maximum and minimum loads for the years 1968–1982.

other vegetation could also remove potassium but this will be an insignificant amount compared to the main plant production. Obviously a certain amount of potassium will be released back to the water when the plants die back and decompose but little information is available on this subject.

The amount of potassium removed by water plants in the stream is only a small proportion compared with the throughput (Table 2). The minimum weekly throughput for the period 1968–1982 was 300 kg/week compared with the plant uptake of 1048 kg a^{-1}. Thus the plant uptake at the lowest load is approximately 7% of the load. Ladle & Casey (1971) showed that for the main *Ranunculus* growing season (April-late May) the uptake of potassium by *Ranunculus* for 27,000 m^2 of stream bed was less than 1% of the load.

CONCLUSIONS

Commercial watercress growing and the addition of potassium fertilisers have a far greater effect on the potassium budget of Bere Stream than the natural plant community. Input of potassium via application of fertilisers is estimated at > 1200 kg a^{-1} (more than the amount calculated to be lost to plant production in the stream, 1048 kg a^{-1}).

Input of potassium loads from rainfall and canopy is negligible compared to the input from groundwater which has a steady concentration of approximately 0.9 mg l^{-1}.

The natural plant removal of potassium from the stream water is only a small proportion of the overall throughput in stream flow (<3%).

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