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HUMAN IMPACT ON THE WATER QUALITY IN A SMALL RESEARCH BASIN IN GERMANY

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ABSTRACT In the past few decades, reconstruction of agricultural areas, particularly vineyards was carried out in the Federal Republic of Germany to increase the productivity. The effects of the reconstruction on the dissolved solutes were studied from November 1982 to mid-September 1983 in an unaltered (small terraced) catchment and an altered (large terraced) catchment in the East Kaiserstuhl. Anion transport was highest from the altered catchment, which probably resulted from the increased impermeable area associated with the installation of a dense network of pipes and mole drains. The increased solute transport was pronounced during winter. Higher transport of ortho-PO_4^{3-} occurred during runoff events throughout the entire year. In contrast, the transport of dissolved solutes, in particular NO_3^-, typically was highest during summer in the unaltered catchment.

INTRODUCTION

In the last 25 years, the landscape of the Eastern Kaiserstuhl, in the southwestern part of the Federal Republic of Germany, has undergone dramatic change. The many small vineyards characteristic of the area have been consolidated to improve the agricultural productivity. The larger terraces and associated changes have had not only visual impacts but a pedological, morphological, hydrological, and hydrochemical impact as well (Keller *et al.*, 1973; Endlicher, 1979; Luft *et al.*, 1981; Demuth & Mauser, 1983; Rieg, 1988; Demuth & Leibundgut, 1990).

The Institute of Physical Geography and Hydrology of the University of Freiburg has been conducting experiments to identify, describe and quantify the hydrological impact of this landscape change, in cooperation with the West German Research Association (DFG). In this paper, the effects of field consolidation on the short- and long-term output pattern of dissolved solutes are examined using data from two neighboring catchments; one was relatively pristine and the other was altered. The study was conducted from November 1982 to 11 September 1983.

THE RESEARCH BASIN IN EAST KAISERSTUHL

The research area is situated about 15 km to the West of the Black Forest in the Eastern part of the Kaiserstuhl well known as a vine growing area and includes an unaltered catchment, Rippach, and an altered catchment, Löchernbach (Fig. 1). The drainage area of the Rippach catchment is 1.2 km^2 and of Löchernbach catchment is 1.7 km^2. Both catchments are underlain by volcanic rock and contain deep loess soils ($\leq$ 30 m). Apart from minor changes, the Rippach catchment has not been altered recently and contains a dense network of irregular foot paths connected to deeply incised roads.

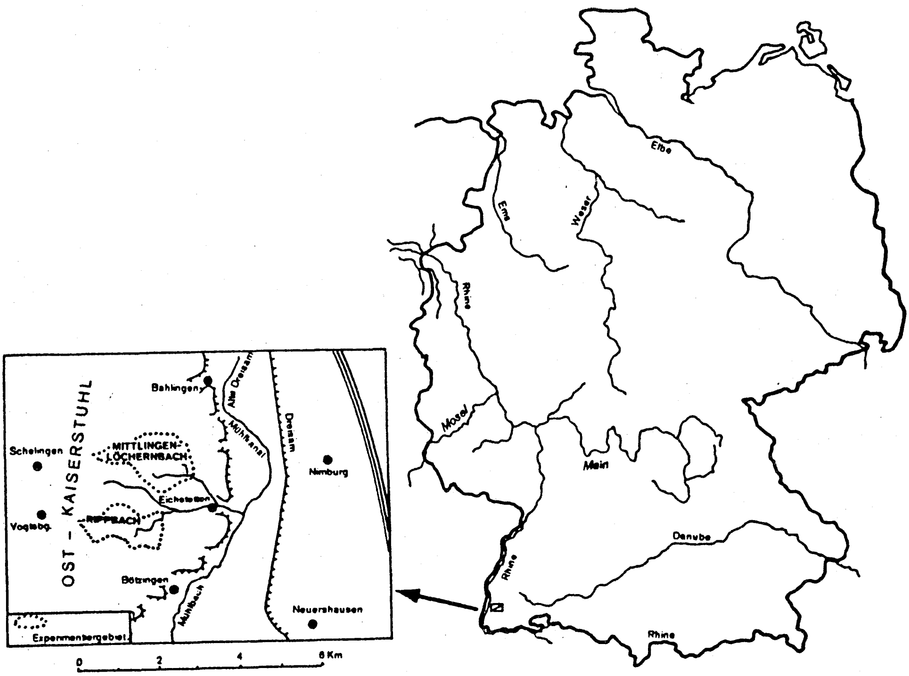


FIG. 1 Location of ihe research basin within the Federal Republic of Germany.

In contrast, the Löchernbach catchment was altered in 1969-1971 and again in 1975-1976, at which time large terraces and a regular network of small roads were constructed using heavy machinery. The consolidation resulted in the construction of very steep slopes at the edges of the new terraces and a dense drainage network. The characteristics of the two catchments are summarized in Table 1.

The instrumentation of the research basins began in 1966 in the Rippach area and was extended to the Löchernbach catchment when consolidation was completed in 1977. Rainfall, runoff, and groundwater levels were continuously monitored at 10 minute intervals. Further details about the instrumentation can be found in Luft (1980).

HYDROLOGICAL BEHAVIOR

The hydrological response of the research basins Rippach and Mittlingen-Löchernbach is shown in Fig. 3 for which monthly mean discharge are plotted against time for the long-term and for water year 1983, which had a wet winter and very dry summer. Since hydrologic monitoring began in the research basins (1972 at Rippach and 1977 at Löchernbach), the highest monthly means occurred in May 1983; the highest discharge was 26 l s^{-1} from the Rippach catchment and 72 l s^{-1} from the Löchernbach catchment. Discharge from the Mittlingen-Löchernbach catchment was higher than from the Rippach catchment for the entire year, except during the low flow period in September. Also, the discharge from the Rippach catchment is less variable than from the Löchernbach catchment throughout the year. In fact, the monthly mean discharge from Löchernbach catchment was more than two times that from the Rippach catchment in the spring.

TABLE 1Catchment characteristics of Rippach and Mittlingen-Löchernbach.

Catchment characteristics	Rippach	Löchernbach
Catchment area	1.2 km^2	1.7 km^2
Length of small asphalt roads	1.4 km	23.2 km
Length of subsoil pipes	<1.0 km	12.3 km
Mole drained areas	-	19.8%
Bank slope of 45°	-	12.%
Land use (in percentage of total area):		
Forest	18.%	5.%
Wine growing area	48.%	65.%
Agricultural land	33.%	12.%
Small asphalt roads	0.5%	6.%

The hydrographs for water year 1983 reflect the differences in storage (Demuth & Leibundgut, 1990). In the Löchernbach catchment, low flow discharge is less than half that of the Rippach catchment. In this paper, the impact that these hydrological differences have on hydrochemistry will be evaluated.

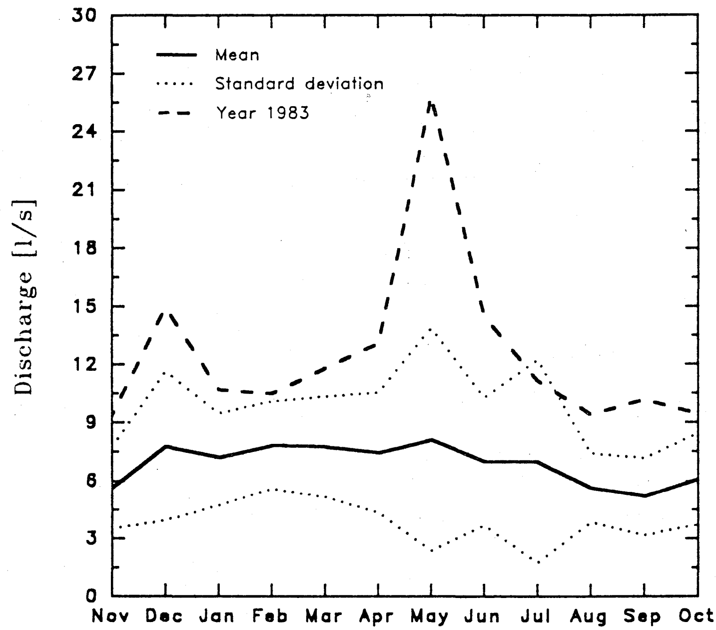
ANNUAL TRANSPORT

Samples were collected weekly during the study. A comparison of flow duration curves for the hydrological year with discharge at the sampling times indicates that the discharge associated with the weekly samples covered 97% of the flow that occurred for the year. Consequently, variations in daily mean discharge are well represented by the samples.

The mean concentration of each solute derived from the weekly samples in the Löchernbach catchment was higher than those from the Rippach catchment and the individual concentrations were more variable. However, for samples collected during storms, the mean concentrations were higher in the Rippach catchment but the range of variation was less. Except for ortho-PO_4^{3-}, solute concentrations are lower during runoff events than during base flow in either catchment. It is important to consider this when evaluating annual transport based on mean daily dissolved load. The cumulative transport of assayed anions including ortho-PO_4^{3-} from each catchment is shown in Fig. 4 for water year 1983.

The total dissolved anion transport was 134 and 128 t km^{-2} from the Rippach and the Löchernbach catchments, respectively. The corresponding mean monthly transport was 13 and 12.8 t km^{-2} from November 1982 to August 1983.

a) Gaging station Rippach



b) Gaging station Löchernbach

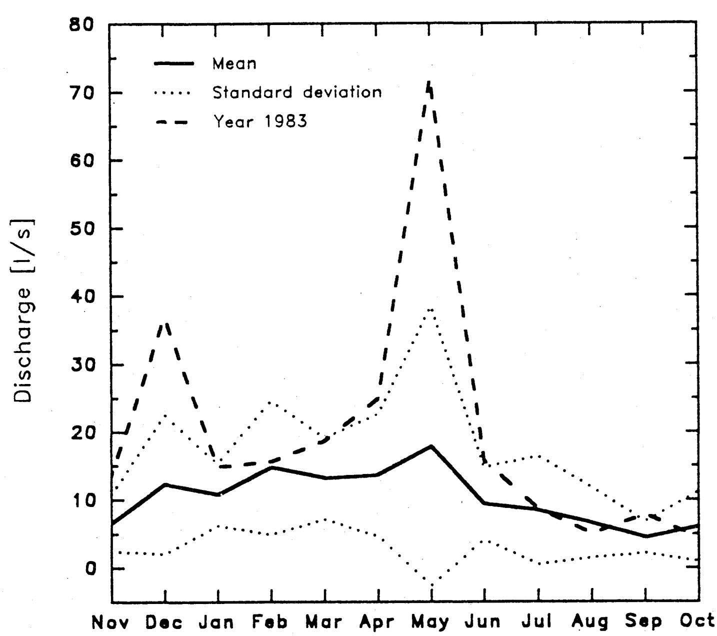
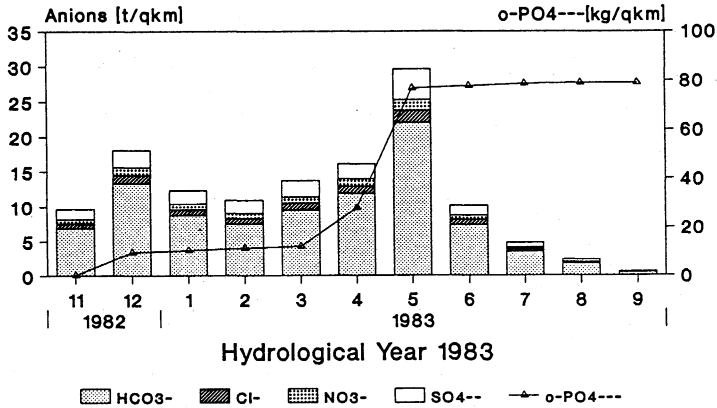


FIG. 3 Comparison of the mean monthly discharges in 1983 with means of the period a) Rippach 1972-1989 b) Löchernbach 1977-1989.

a) Gaging station Löchernbach



b) Gaging station Rippach

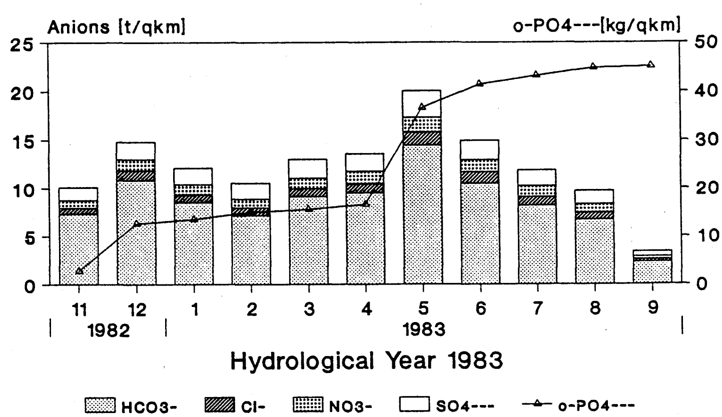


FIG. 4 Mean monthly dissolved loads in 1983 at a) Löchernbach and b) Rippach.

Surprisingly, the transport from one catchment is similar to the other. However, in winter, which included May 1983, the output of anions from the Löchernbach catchment was 17% more than from the Rippach catchment. The higher total anion content in the Löchernbach catchment during winter is not only caused by higher discharge but concentrations were higher as well. This observation applies to all anions except NO_3^- and suggests that the current consolidation processes also may have an effect. However, the higher total chemical output in the Rippach basin is primarily effected by high discharge during low flow periods such as the very dry and short summer of 1983.

SHORT-TERM TRANSPORT

Storm samples were collected for chemical analysis to investigate human impact on the hydrochemistry and solute transport from the basins. Discharge at each site for a thunderstorm with an average intensity of 5 mm h^{-1}, which occurred on 10 September 1983, is shown in Fig.5. This storm marked the end of the dry summer season in 1983. Lowest flows for the year occurred at each station on the previous day.

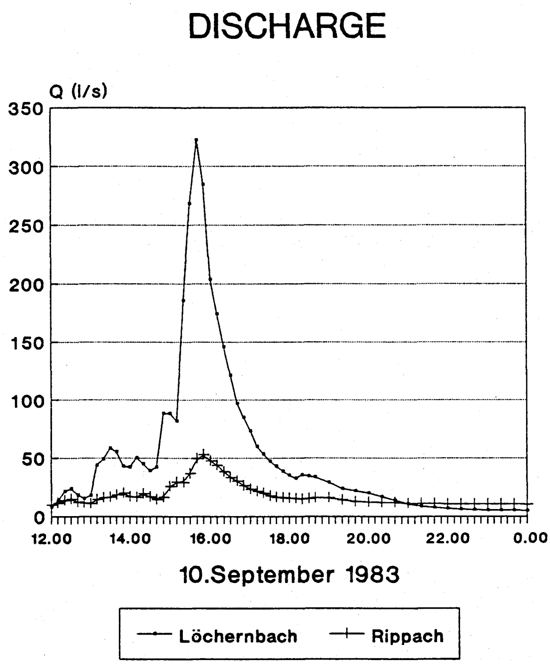


FIG. 5 Comparison of discharge values on 10 September 1983 at the Rippach- and Löchernbach-gage.

Earlier investigations of these catchments, which focused on modelling runoff processes, showed that the amount of total runoff in the consolidated basin is almost three times higher than in the non-consolidated basin (Bucher, 1985). Solute concentrations for all anions except ortho-PO_4^{3-} differ very much and, in part, reflect the differences in runoff. Examples for Ca^{2+} and Cl^- are given in Fig. 6.

At the beginning of the storm, Ca^{2+} concentrations at Löchernbach were only 4.5 meq l^{-1} suggesting that very poorly mineralized water from the roads and the drainage network must have passed the site very quickly. At this time corresponding values at the Rippach gage were about 6 meq l^{-1}. It is interesting to note that this was inconsistent with the general pattern, i.e. higher concentrations were normally observed in the Löchernbach catchment. Cl^- behaved similarly (Fig. 6b).

Ortho-PO_4^{3-} concentrations increased as discharge increased and this increase is attributed to higher amounts of surface flow and adsorption of PO_4^{3-} on suspended solids (Fig. 7). In addition, the maximum concentration was highest at the Rippach gage. The con-

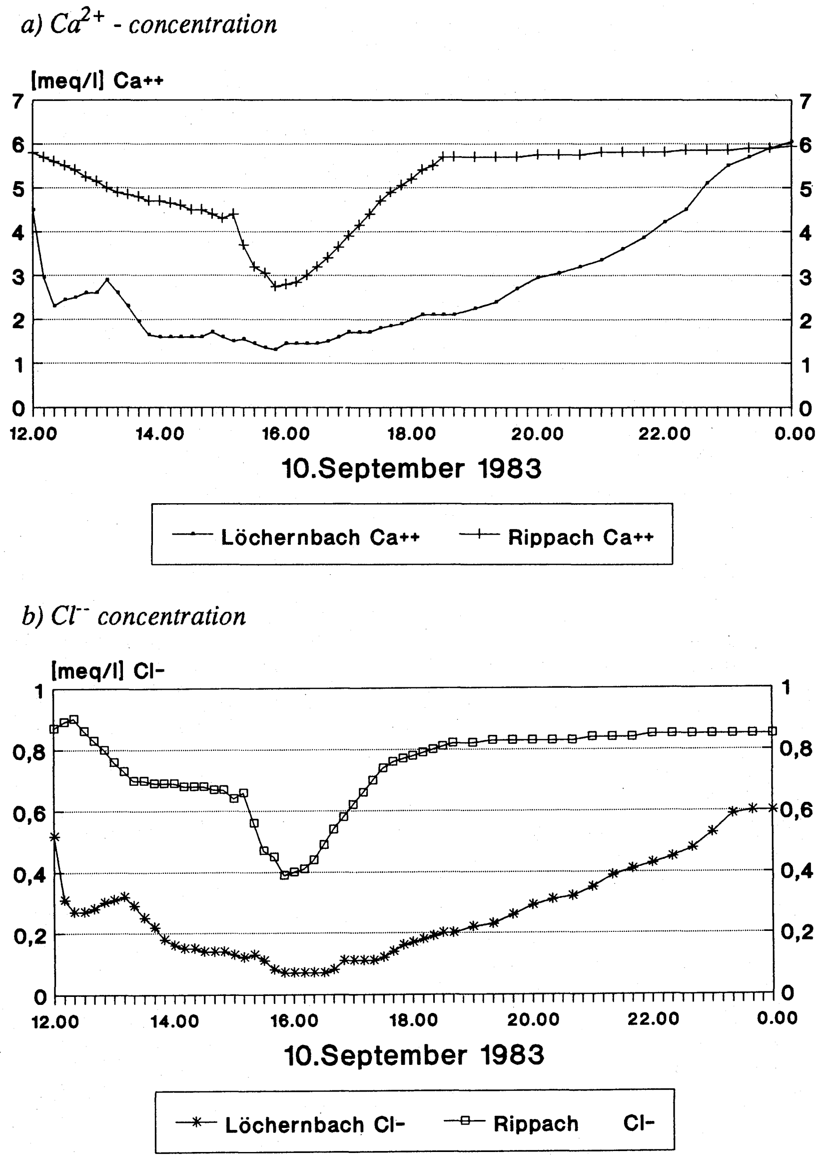


FIG. 6 Comparison of concentration curves for a)Ca^{2+} *and b)*Cl^- *at the sites Löchernbach and Rippach*

centrations are based on data collected at less than the 10 min intervals for the runoff record. Because they are taken at more frequent intervals the curves were smoothed. Smoothing the curves made it easier to compute short-term loads, but it masked the real variation in concentration. By using a shorter sampling period, larger changes in rainfall intensity then was recorded in the 10-min interval were apparent.

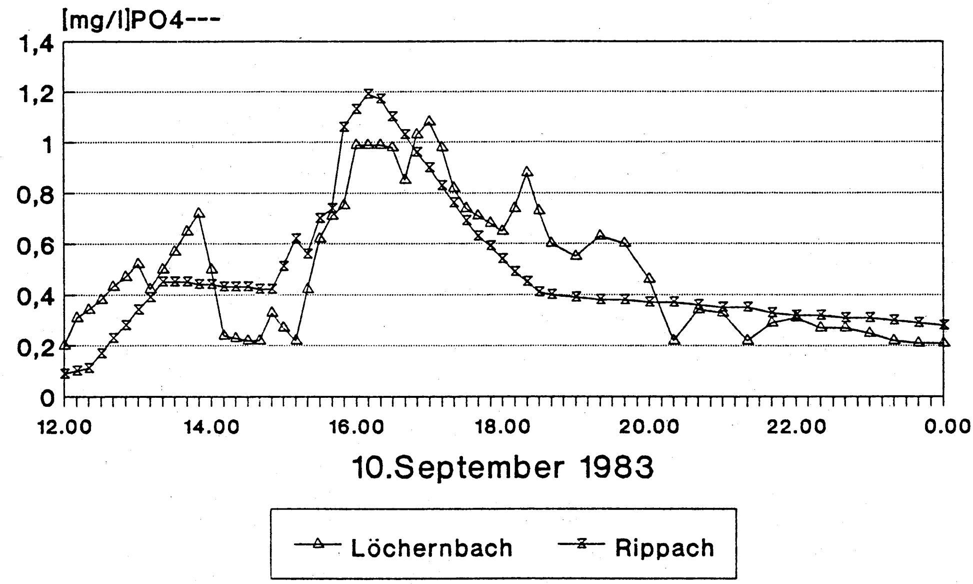


FIG. 7 Comparison of ortho-PO_4^{3-} concentration at 10-min. intervals during an runoff event at the Löchernbach- and the Rippach site.

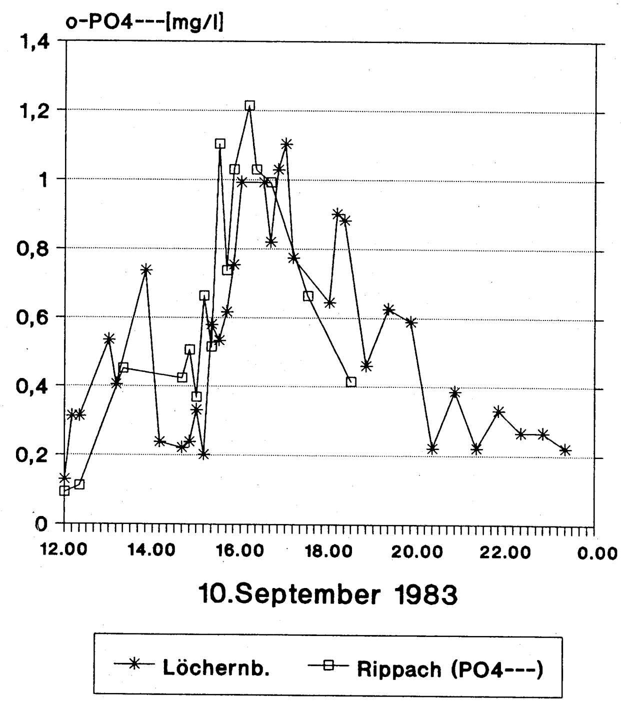


FIG. 8 Comparison of ortho-PO_4^{3-} concentration values at the Löchernbach- and the Rippach gage.

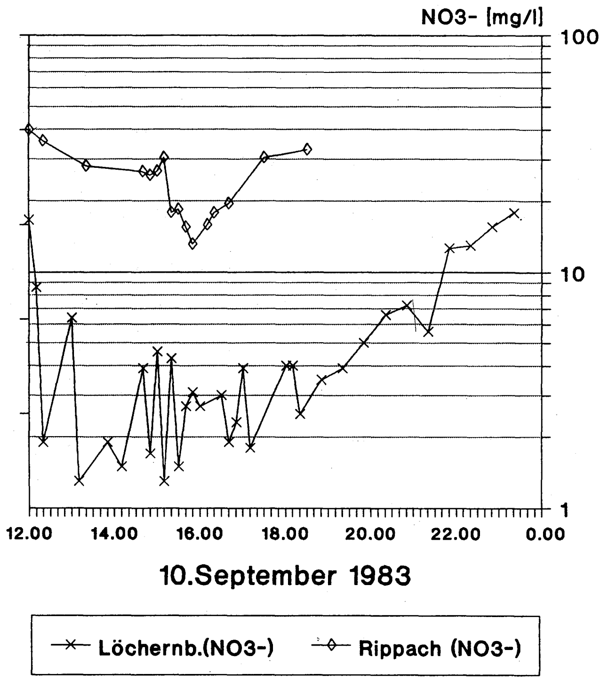


FIG. 9 Comparision of NO_3^- concentration values at the Löchernbach- and the Rippach gage.

CONCLUSIONS

Catchment characteristics affect different responses to system input and cause different variations in concentration. In a sensitive system, such as in the Löchernbach catchment, larger variations in concentrations occur than in the nearly natural Rippach basin.

Two possible sources of the ions are needed to produce such hydrological behavior:

(1) Constant or steady input into the drainage system from the catchment caused by the diffuse infiltration of the precipitation; and

(2) activation and input into the drainage system like a shock wave caused by surface run-off.

The behavior of NO_3^- (Type a) and ortho-PO_4^{3-} (Type b) fit these conditions and should be capable of use as natural tracers. The concentrations of each ion is shown in Fig. 8 and in Fig. 9. The curves have not been smoothed and show the real variation of concentration at each site.

The ortho-PO_4^{3-} concentrations show that the maximum at the Rippach catchment is in fact higher than at the Löchernbach catchment and that large variations in concentration occur. At the Rippach gage, variations are smaller and appear to be primarily affected by discharge. This may have been caused by fewer samples being collected during the runoff recession.

The NO_3^- concentrations show a different pattern. The minimum is lower at the Löchernbach catchment but larger variations in concentration are observed there than at the Rippach catchment.

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