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Variations in time and space of some physical and chemical variables in the Bernesga river (León, Spain)

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The chemical composition of the river Bernesga has been evaluated throughout four seasonal sampling studies at twelve sampling points. The tendency towards an increase in mineralization all along the river can be observed when using a principal component analysis to the complete data gathered. A temporal differentiation based on the variations which affect the flow rate through out the year is also established.

The spatial organization defined by the second component enables us to use the scores as the starting point in order to determine the value of the chemical distance between the different sampling stations. The contrast between the chemical and actual distance gives an overall view of the river, which is a reflection of what happens on its course with regard to its chemical processes.

Variations spatio-temporelle de la composition physico-chimique de la rivière Bernesga (León, Espagne).

Mots clés : Physico-chimie, rivières.

12 stations ont été échantillonnées aux 4 saisons pour étudier la composition chimique des eaux de la rivière Bernesga. L'analyse de l'ensemble des données par une méthode en composantes principales révèle une augmentation de la minéralisation le long de la rivière. Des différences temporelles liées aux variations qui affectent le volume d'eau au cours des saisons sont également établies.

L'organisation spatiale définie par la seconde composante nous permet de déterminer une distance chimique entre les différentes stations. La comparaison entre la distance chimique et la distance réelle donne un reflet général des processus chimiques qui se déroulent sur le cours de la rivière.

1. Introduction

A fluvial system should be regarded as a functional continuum (Margalef 1983). The concept of a river as a continuum put forward by Vannote et al. (1980) which is based on the gradient analysis, considers the river course as a longitudinally connecting system, where the processes which take place along the lower stretches are linked to the processes that develop along the upper stretches. This concept gives us a general idea as to how to regard rivers as heterogeneous systems (O'Neill et al. 1979).

The chemical composition of rivers, under natural conditions, is controlled by a series of factors (Gorham 1961, Gibbs 1970) such as climate, vegetation and topographic and geological characteristics of the catchment area. Capblancq & Tourenq (1978) recognize a greater dependency of the catchment area litological characteristics for a temperate zone and to this, the influence of human activities must be added.

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In the Bernesga river, the last of these factors acquires special relevance since the water composition is affected by built-up areas along the river which cause a lot of pollution in some cases of industrial origin.

This paper may be considered as a continuation of the study carried out by Fernández et al. (1987), which has been useful in characterizing the rivers within the Bernesga catchment area, specially from a chemical point of view. In this particular case, the study is exclusively related to the river which gives its name to this watershed and tries to analyse its functional dynamics from the chemical composition of the water point of view. The chemical picture derived from this analysis will allow us to evaluate the temporal variability and to establish how human environmental conditions affect it.

2. Description of the study area

The Bernesga flows from north to south in León province (Northwest Spain) (*fig.* 1). Its source is situated near Pajares mountain Pass, at an altitude of 1 600 m, and flows into the Esla river after an 80 km course approx. Having passed León city, the Torío, its main tributary coming from the left, joins it.

The upper part of its course, which is an almost complete mountainous watershed, mainly flows through palaeozoic soil of great litological variety with carboniferous materials having the greatest complexity and superficial extension. Limestone is common in this area and form strata with quartz, shale and sandstone. In La Robla, one of the main built-up areas, the river leaves its mountain relief and flows into a flat area where tertiary miocene soil gains are important. It is made up of clay, sandstone and marl mixed detrital quartz sediment of a loose quartz gravel nature (rañas).

Up to La Robla, the Bernesga flows through an area of warm, fresh humid Mediterranean type climate (Papadakis 1961). After this point and up to its flowing into the Esla it passes through an area of warm, dry Mediterranean type and only along a short stretch where it joins the Elsa does it flow through and arid type climate, which Papadakis defines as a semi-arid, semi-warm continental Mediterranean type climate.

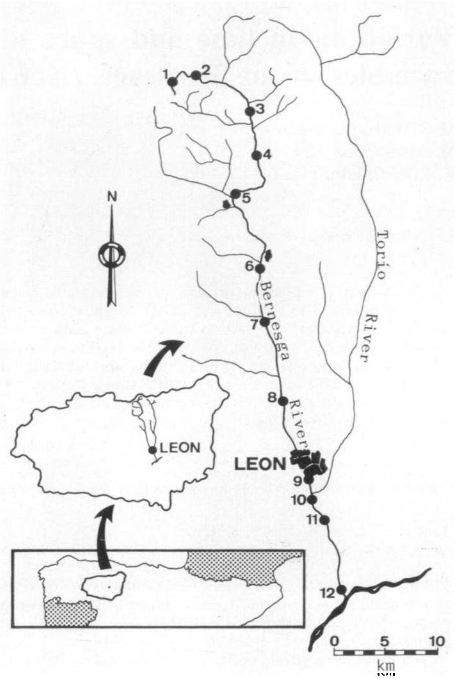

Fig. 1. Geographic situation of the river Bernesga and location of sampling stations.

The mediterranean type climate is reflected in the river's hydro system. The larger floods usually occur in March and April while the flow rate falls during summer. The overall Bernesga system mainly depends on the contributions of the upper area of the watershed, to such an extent that there are notable differences in the water volume over a yearly period (Fernández 1986).

3. Methodology

Twelve sampling stations on the river were visited in autumn 1985 and in the winter, spring and summer of 1986 (*fig.* 1). The pH, dissolved

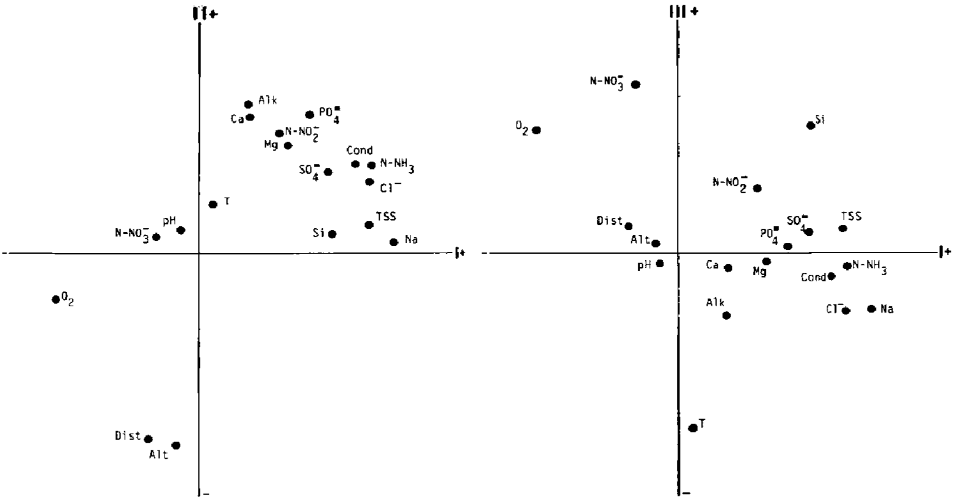

Fig. 2. Distribution of the physical-chemical and the geographical variables on the planes defined by a) components I and II, and b) I and III.

oxygen concentration, water temperature and conductivity were measured. In each water sample collected at each station, the following parameters were assessed in the laboratory : total alkalinity (volumetric method, Golterman et at. 1979), magnesium (complexiometric method, Standard Methods 1980), sulphate (turbidimetric method, Standard Methods 1980) and total solids in suspension (filtration method, Rodier 1981). Phosphate concentration (Murphy & Riley 1962), silicates (Standard Methods 1980), nitrites (Shinn 1941) and nitrates (Standard Methods 1975) were all assessed using the colorimetric method. Selective Orion electrodes (models 99-17B, 95-12, 97-11, 93-19 and 93-20 respectively) were used in the chloride, ammonia, sodium, potassium and calcium analysis. The altitude and the distance to the mouth were also calculated.

Statistic processing of the data was carried out using a principal component analysis and following the « Factor Analysis BMDP4M » programme (1982). A transformation of the $x = \log(x + 0{,}001)$ type for all variables except for the pH was performed (Cassie 1963, Ibanez 1971).

4. Results

The results obtained were evaluated using a principal component analysis in order to find out how different conditions which follow one another throughout a seasonal cycle have an effect on the behaviour of the variables analysed and on the physical-chemical pattern of the river.

The first three factors of this analysis give 62,85 % of the total variance. Sodium, ammonia, chloride and solids in suspension are the parameters with a higher positive correlation with regard to the first axis (25,62 %) contrary to dissolved oxygen which is associated with the negative end of this axis (*fig.* 2). This axis can be identified with an enrichment with those variables directely related to the influence of human activities along the river, which, at the same time, decrease the concentration of dissolved oxygen.

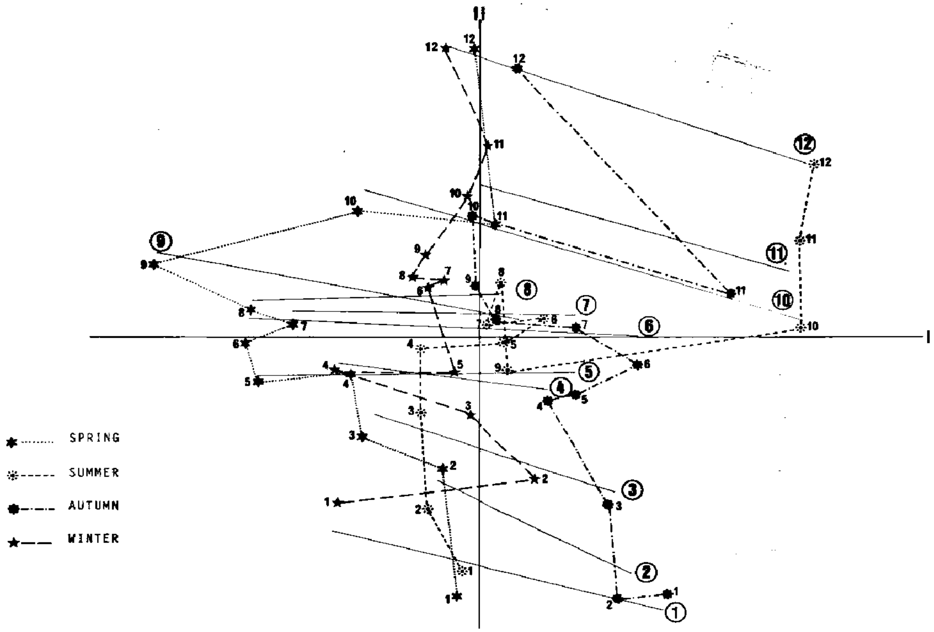

Fig. 3. Arrangement of the sampling stations on the plane defined by two first principal components. For each a regression line has been drawn up using the values of different samplings.

Alkalinity and calcium are at the positive end of component II, while altitude above sea level of each station and their distance from the mouth are at the negative end. This pattern obviously reflects the general tendency which appears along a riverbed with a progressive increase in the salt content (Margalef 1983). Two points should be noted with regard to this gradient ; the first is the association of phosphates with Ca^{++} et $HCO3^{-}$ concentrations ; the second is the lack of a good relationship between the tendency defined by second component and conductivity, because the influence of sulphates and chlorides have on this parameter. Cl^{-} and $SO4^{--}$ are clearly linked to the pollution expressed by the first axis.

A clear contrast between nitrates, dissolved oxygen and silicates, which appear linked at the positive end, and temperature, which remains isolated at the opposite end (*fig.* 2) appears on the third axis (13,46 %). Such a disposition can be explained by the inverse relationship between water temperature and oxygen solubility, and by the increase of the concentration of nitrates in autumn and winter, coinciding with a drop in temperature and a reduction of photosynthesis.

The arrangement of sampling stations on the plane defined by the first and second components (*fig.* 3) varies considerably in autumn as station 11 moves towards the positive end of the first component, owing the abnormally high levels of

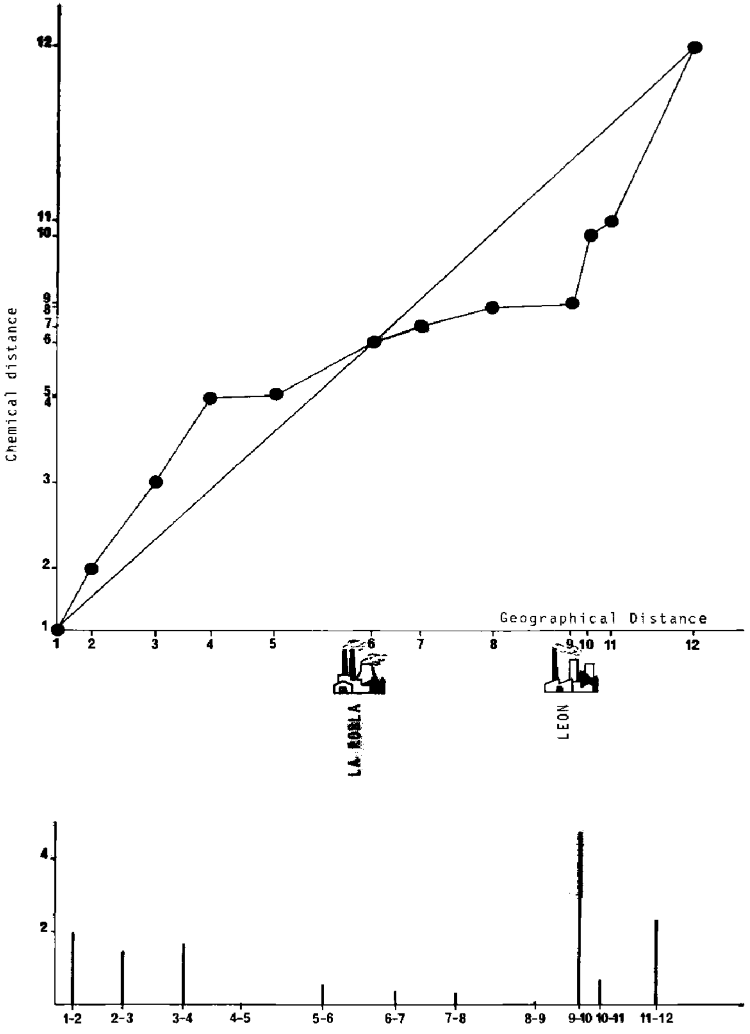

Fig. 4. Graphical comparison between the chemical and geographical distances of the sampling stations and the representation of the angle of the straight line between two successive stations as an expression of the rate of change in their chemical composition.

conductivity, total solids in suspension, chlorides and ammonia. This situation may have arisen because of the coincidence at the time of sampling with a highly polluted water flood from upstream.

In summer, the sequential arrangement does not always remain the same along the second axis as there is no clearly defined tendency towards an increase in mineralization along the middle section, between station 5 to 9. At the latter station at León city, before the sewer outlets, the alkalinity and calcium levels drop considerably.

The first component reflects seasonal differences of the sampling stations. The reduction in flow rate throughout the year, cause an enrichment in chlorides, sodium, ammonia and sulphates, and an accentuation of the pollution (*fig.* 3).

The effect of León city sewage on the chemical composition of the water in sampling stations further down from the city (10,11 and 12) can clearly be seen in summer owing to the shift of these stations to the positive end of the first axis. This demontrates the larger variation of the chemical composition along the river in the summer period, while a larger homogeneity, with regard to the gradient defined by the second component, appears in the winter.

If we considerer the dispersion of a station on a plane defined by the first two components, the degree of seasonal variation which takes place in its chemical composition can be evaluated. Regression lines which belong to each sampling station have been drawn up for this reason, and from the results, the slightest variability throughout the yearly period at stations two and four can be seen, while the greater differences occur in stations six and ten which are directly affected by the urban areas of La Robla and León respectively.

5. Discussion

The principal component analysis demonstrates a spatial organization of the changes of the concentrations of dissolved salts in the Bernesga. A chemical distance can be estimated for each station and it can be compared with the geographical distance. The values which correspond to the second principal component, converted in kilometers and standardized to the real length of the river have been considered as chemical distance.

The representation of the chemical as opposed to the geographical distances makes it possible to detect the changes in the chemical composition at several stations along the upper course of the river. Stations 1, 2, 3 and 4 show a larger chemical difference than geographical distance. This performance at the stations along the upper part of the river has been found by Sabater & Armengol (1985) in the river Ter. It reflects the effect that small polluted discharges have on an unbuffered and scarcely mineralized water. In the Bernesga, these impacts are limited to the impact of mines situated between stations 1 and 2, and the effects caused by the villages of the area (Busdongo, Villanueva de la Tercia and Villamanin). However, in the stations 5 to 9 the chemical distances are smaller than could be expected when considering their geography : a uniformity in the chemical composition is produced which confirms the general tendency pointed out by Margalef (1983) and Sabater & Armengol (1985) towards a stabilization in the chemical composition and the acquisition of a chemical inertia as drained surface increases. The small impact which the industrial city of La Robla has on the patterns in the river, compared with the perturbations in the initial stretch of the course, can be explained because of this inertia. However, this stability does not persist because domestic and industrial sewages drastically modify the chemical composition of the water in the final course and amplify the chemical distance in relation with the geographical distance. The patterns of stations 10 and 11 which are directly affected by the sewage are similar. A predominance of the polluting process over the influence which the upper stretches exert can, therefore, be established, and, as a consequence, a discontinuity of the river's functions arises.

These results can be obtained by plotting the linear slope of the line which links two successive stations (*fig.* 4). Three stretches can be distinguished : the first (stations 1-4) and the third (stations 10-12) with a higher slope than 1 : 1 and a second (4-9) with a smaller slope. Therefore chemically the river lengthens in the first and third stretches and shortens in the second.

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