Water quality models of the rivers Nalón, Caudal and Nora (Spain)

I. Tejero, A. Ascorbe, A. Liaño, M. Presmanes, J.A. Sáinz y J. Suárez

Department of Water and Environment, University of Cantabria, Santander, España

ABSTRACT

The object of this study was the development of models of the water quality of the rives Nalón, Caudal and Nora (Asturias, Spain). The said models will be used in the sewerage planning of the catchment areas. The theoretical model QUAL2E was used.

The first approximation to the model is made by using *premodels*, which are the result of the application of QUAL2E to the rivers without carrying out specific calibration field studies, using data available from other studies or easily obtained data gathered for the purpose. Afterwards, the steps of calibration and validation of the models is done by specific field studies. The premodels are to be used as inexpensive and rapid tools.

This study has allowed us to discover the influence of peculiar and isolated phenomena, such as uncontrolled industrial waste water discharge. It was observed that the model fit was much better in the case of rivers with large flow than it was in the case of small flow and high contamination. The reaeration models were chosen which fitted our type of river best.

INTRODUCTION

The construction of simulation models of the water quality of the rivers Nalón, Caudal and Nora (figure 1) was carried out for the purpose of obtaining a tool for the planning of sewerage and wastewater treatment work, and for determining the minimum flows.

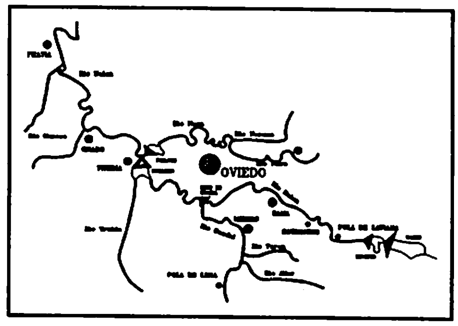

Fig.1 Location of rivers Nalón, Caudal and Nora

The main characteristics of these rivers is their steep gradient and short length. The Caudal and Nora are tributaries of the river Nalón. The lowest flows occur in the summer. The estimated minimum flows for the last stretch modelled are 1.85, 2.40 and 0.55 cubic metres per second for the Nalón, Caudal and Nora respectively.

The catchment area, 1960 squared kilometres, is characterised historically by having coal mines and, consequently, important industrial areas and centres of population.

A model which attempts to simulate the quality and contamination of the water of a river must be able to adequately represent the physical, chemical and biological phenomena in a sufficiently close way.

With a view to the planning of sewerage and treatment of wastewater discharges in a hydrographic catchment area, various models or structural theories have been developed. In this work model QUAL-II (Brown and Barnwell,[1]), in its version QUAL2E (NCASI), of the United States Environment Protection Agency (US-EPA) was used.

GENERAL METHODOLOGY

The application of model QUAL2E to a hydraulic system formed by a river and its tributaries involves a laborious process which, according to the authors, comprises the following steps:

a) work out a premodel
b) construct the initial model by calibration
c) validate the initial model to obtain final model
d) monitoring and updating of final model.

A database has been designed to process the data necessary for the production of the models of water quality. The database includes information about wastewater point discharges and water quality of the rivers. Finally, the river models, the database, and the graphics output produced with standard software have been united to form a collective tool. In this way the information can be updated and processed easily.

PREMODEL. METHODOLOGY

We call *premodel* the result of the application of the model QUAL2E to a specific river, without carrying out in the specific field studies, using data available in other studies, or easily obtained data gathered for the purpose. We aim to apply the model to an unfavourable situation (minimum flow, simultaneous waste water discharges, etc.) in such a way that the resulting simulation includes the use of the available data.

The interest which the setting up of the premodel has lies in, on the one hand, the relative speed with which guiding results can be obtained by simulation and, on the other hand, the information which it affords with a view to the design of specific field studies for the next stage of the initial model construction.

In establishing the parameter values, although in the model user manuals a typical range of variation is shown for each of them, the choice of each actual value depends on the user's criteria and experience acquired in similar situations (Ascorbe et al,[2]).

Construction of the premodels

We considered as minimum flow that equalled or exceeded in 360 days in 90% of the years.

As for the hydraulic flow, we adopted a Manning type, with roughness coefficient values deduced from the results of the velocities measurement field survey carried out in July 1988, using floats technique.

As leads of the rivers we chose the gauging station E-363 for the river Caudal, Piñeres on the river Aller, San Andrés on the river Turón, gauging station E-335 on the river Nalón, and Pola de Siero on the river Nora. As end points we took the confluence of the rivers Nalón and Caudal for both rivers and the Priañes dam for the river Nora. In table 1 the main characteristics of the model are summarised. In the river Nora areas of great contamination are found reaching levels of anoxia (figure 2).

Table 1. Main characteristics of the model

RIVERS	NALON	CAUDAL	NORA
No. of reaches	14	10	17
No. of heads	2	3	2
Tributaries	Sta.Bárbara	Aller Turón	Noreña
No. of elements	53	79	137
Length of element (mts)	800	660	500
Length of river model (km)	40.8	33	67.5
Gradient of the river	0.00495	0.00719	0.00238
Flow of heading element (m^3/s)	1.31	1.11	0.15
Flow of last element (m^3/s)	3.08	4.13	1.11

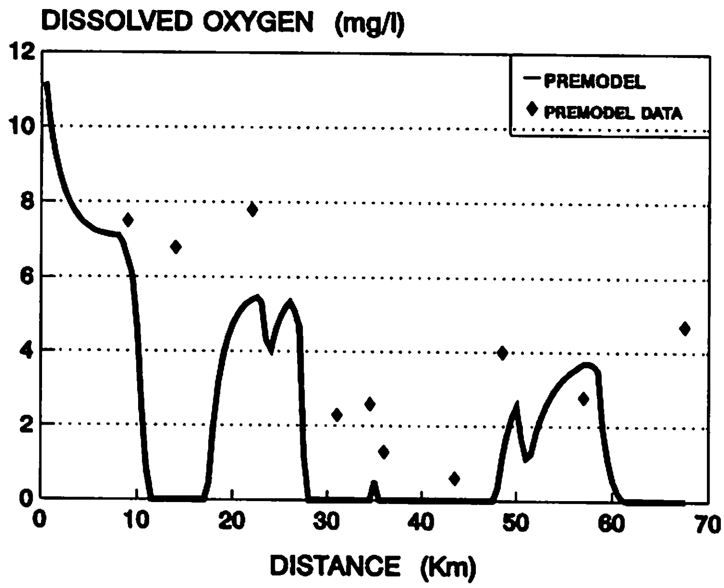

Fig.2 River Nora. Premodel

As a large part of the industrial waste water discharges is produced by mining, we considered the necessity of including suspended solids as a reactive contaminant (figure 3)

CALIBRATION. METHODOLOGY

We call the result of applying model QUAL2E to a specific river the *initial model*, using the results of a specific field study for this.

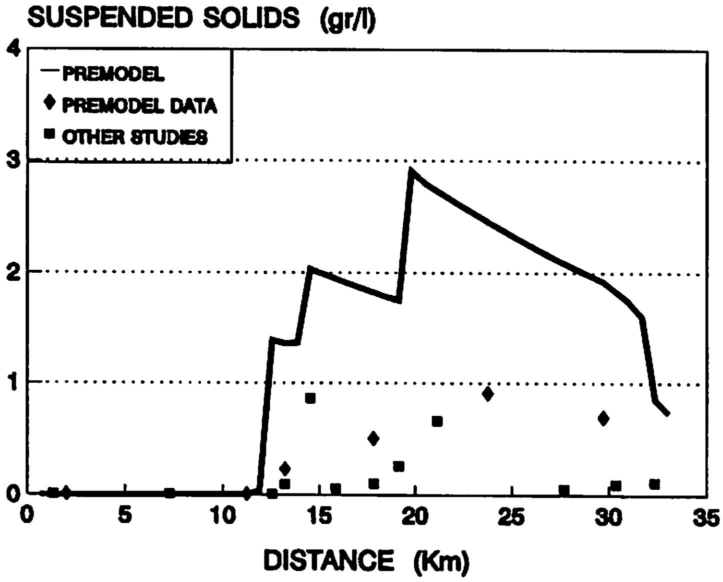

Fig.3 River Caudal. Premodel

With respect to the hydraulic characterisation, it is necessary to bear in mind that the initial model attempts to reflect the behaviour of the river in a specific situation: namely that existing during the quality measuring field study. This programme was carried out in the months of August and September 1988, so that it reflects a minimum flow situation, with the advantage that variations in the flow during periods of 3 or 4 weeks are not important. This last consideration means that no noticeable variation in the river flow occurred due to the different dates of the velocity and quality field studies. Chemical traces (potassium dichromat) were used to carry out the programme.

Although the ideal, from a theoretical viewpoint, would be to have perfect knowledge of the water quality at each point and each instant, it is obviously practically impossible to achieve this. For this reason, from the spatial aspect, a series of specific points were selected, spread throughout the length of the different stretches of river considered and, from the time aspect, it was thought adequate to take three readings throughout the day at each point, with time intervals of 8 hours.

Bearing in mind that the model QUAL2E is used to represent steady states, the design of the water quality field study was carried out on the basis of the *follow the drop* criterion. Thus, the precise time at which to take the samples at each selected points was determined as a function of the travel times calculated from the velocity field survey previously mentioned.

The characterisation of the waste water discharges was based on studies and measurements done previous to the calibration field study, average daily contamination values being thus defined.

Construction of the models. Calibration.

The hydraulic flow model adopted is the Manning type, based on the velocity field study.

As for the calibration stage, the determination of de rates of reaeration of the river were made as result of the fitting of the dissolved oxygen values. Fixed values of the said rates were obtained in each reach of river, leaving questionable their extrapolation to other situations with flows different to those existing during the calibration field study.

In figures 4 and 5 the model and premodel are compared for the profile of flows corresponding to the calibration field study.

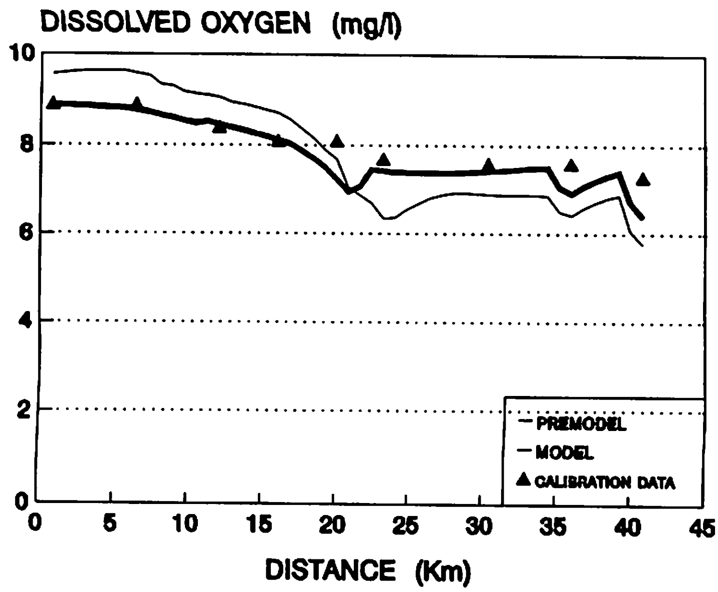

Fig.4 River Nalón. Calibration

A stated fact was the difficulty of simulating (with the model QUAL2E) very different reaches of river in the same model, due to the setting of a constant value for the length of the calculation element in the entire river. This was the case with the river Caudal, in which the simulation of the river Turón, which required very small (50 to 100 metres) lengths of the calculation element could not have been very good.

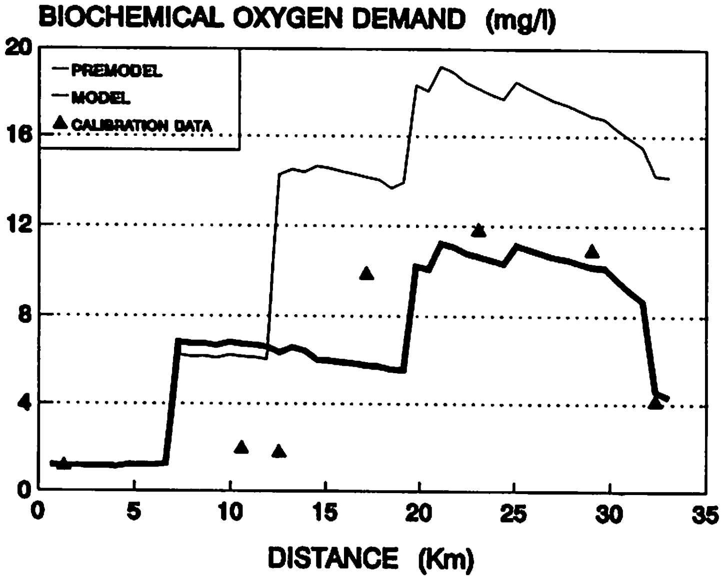

Fig.5 River Caudal. Calibration

We also detected a strange nitrification phenomenon in the river Nalón, with apparent inhibition of nitration, giving place to the consequent accumulation of nitrites in the river. This phenomenon was due to an uncontrolled industrial waste water discharge and did not appear in the later validation field study.

We have glimpsed the possible existence of phenomena not considered by QUAL2E (precipitation of phosphorus dissolved by seepage from quarries, denitrification by the anaerobic bed of the river, increase in turbidity due to suspended carbon, etc.) which can produce certain errors in model calibration.

We did encountered great difficulties in carrying out the river Nora field studies. This was due to the low flow velocities, with the existence of numerous weirs and low flow volumes. This characteristics make the elaboration of the flow model in such small rivers very complex (Ascorbe at al,[3]). Moreover, its high level of contamination causes anoxia in some stretches of the river, which means that it does not fit the hypothesis used in applying QUAL2E.

VALIDATION. METHODOLOGY.

For the validation we carried out a specific field study in the first half of October, 1989. This programme covered the following: velocity field survey with rhodamine WT as tracer, previous to the simultaneous water quality and point discharge contamination field studies. The *follow the drop* method was again used, with 3 samples taken at 8 hour intervals.

Recalibration

The initial validation for the river Nalón and Caudal models gave rather unsatisfactory results, which forced us to do a model recalibration. We therefore reconsidered the treatment given to the determination of the rate of river reaeration in the different reaches. We tried to make the geometric-hydraulic characteristics of the river produce the said values in an automatic way, thus making the model extrapolation easy. To do this we did a comparative analysis of the results of each of the 6 empirical models of reaeration considered in the QUAL2E model, finally adopting the proposal of Langbien and Durum [4].

Once these modification were made, we turned to the recalibration of the model with data sets of the calibration field study (figures 6 and 7).

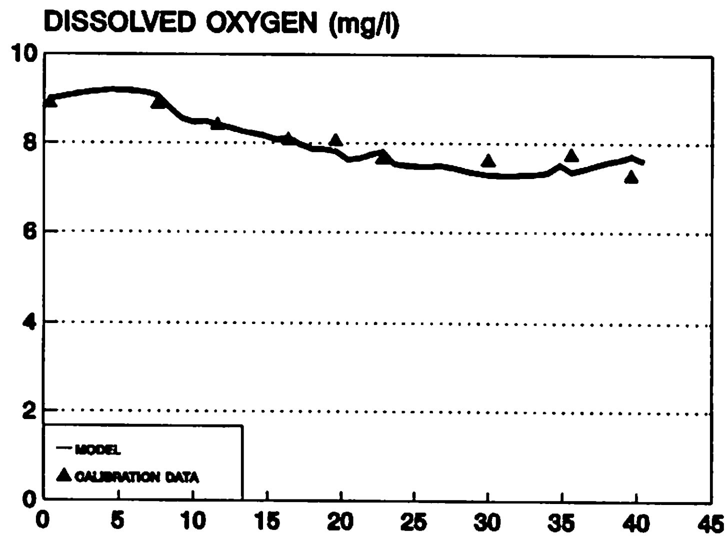

Fig.6 River Nalón. Recalibration

On analyzing the variation of nitrogen content total, we observed the existence of a certain deficit, which shows the existence of nitrogen addition in a progressive way throughout the length of both rivers. Non print sources of contamination, mines, and urban wastewater were thought of as possible contributing factors. We considered that the first two were more relevant as, in this river catchments, nitrogen concentration in the form of nitrates can exceed 20 ppm in subterranean aquifers, and water coming from mines can reach appreciable nitrate concentration levels (4.6 mg/l).

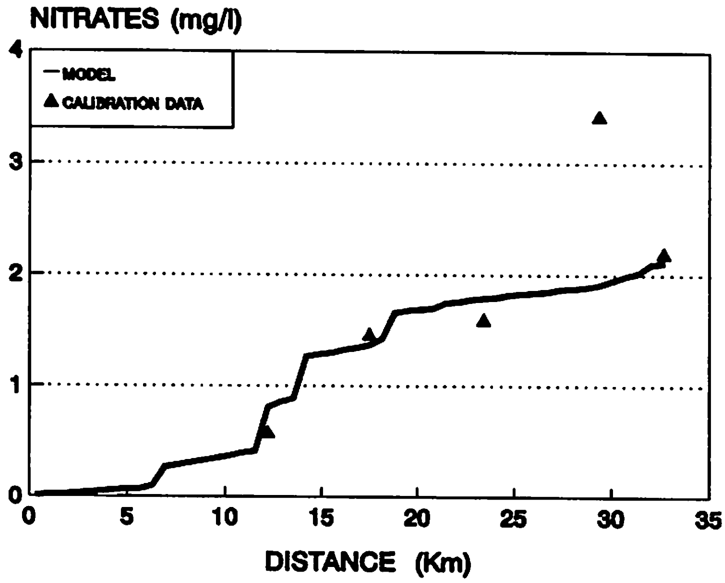

Fig.7 River Caudal. Recalibration

<u>Final validation</u>

We proceeded with the validation of the models recalibrated with the validation field study, with the result of a fit which we consider acceptable (figures 8 and 9), the main characteristics of the approved model being shown in table 2.

CONCLUSIONS

The premodel, as defined, proved useful, although experience was a large influence in its construction.

The classic methodology of a modelling process had to be modified, bearing in mind the results obtained in the initial validation of the calibrated models. Thus, a *recalibration* of the initial model was done, which produced an acceptable *revalidation*. In practice, it can be considered that a model calibration was done with two independent field studies.

The empirical reaeration model which is best suited to our rivers is that of Langbien and Durum.

The analysis of measured data, using the models in their different stages, has allowed us to detect special phenomena which have been present in the rivers during the monitoring programmes.

Table 2.- Characteristics of the final model

RIVERS	NALON	CAUDAL
Flow of heading element (m^3/s)	2.10	0.60
Flow of last element (m^3/seg)	3.83	3.49
Hydraulic flow model	Manning	Manning
Total course time (h)	44	32
People	81,772	75,945
No. of point loads	229	119
No. of elements with loads	35	46
Sum of loads flow (m^3/s)	1.149	1.237
CONTAMINATION (Kg/day)		
BOD	5,616	5,198
Suspended solids	1,753,975	539,649
Ammoniacal nitrogen	619	178
Organic nitrogen	767	324
Dissolved phosphorus	226	109

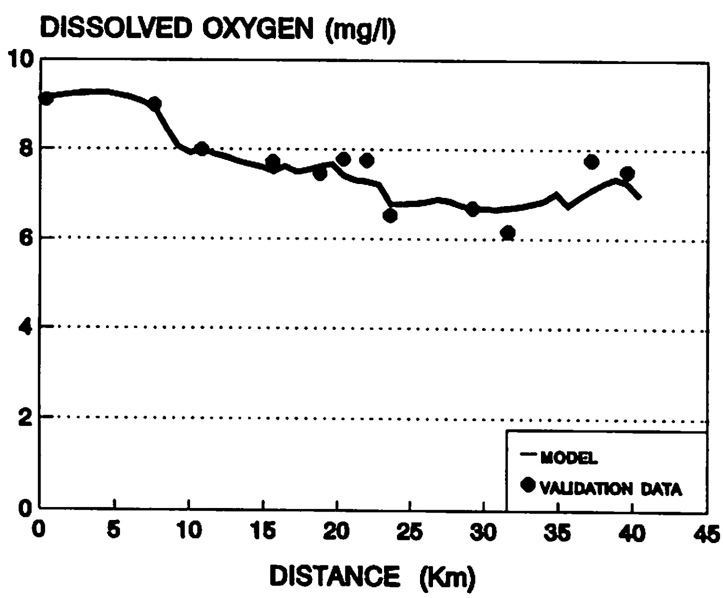

Fig.8 River Nalón. Validation

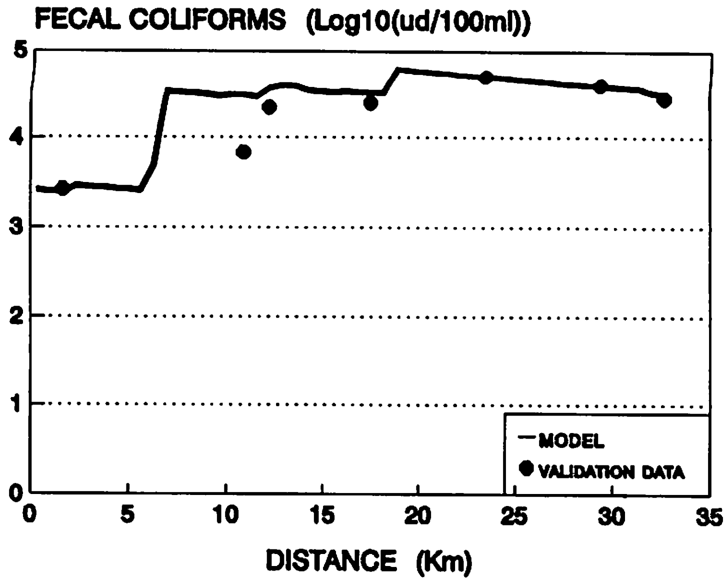

Fig.9 River Caudal. Validation

ACKNOWLEDGEMENTS

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REFERENCES

[1] Brown, L. and Barnwell, T. *Computer Program Documentation for the Stream Quality Model QUAL II. Version Qual2e.* U.S. Environmental Protection Agency. 1985.

[2] Tejero, I. et al. *Modelos de la Calidad de las Aguas de los Ríos Nalón, Caudal y Nora.* Fundación Torres Quevedo. Santander, 1988-1991.

[3] Ascorbe, A., Gómez Poncela, J.M., Presmanes, M. y Tejero, J.I. 'Aplicación del Modelo QUAL II al Río Campiazo (Cantabria)'. *Modelos de Calidad del Agua.* Ed. Prensa XXI. Barcelona, 1990.

[4] Langbien, W.B. y Durum, W.H. 'The Aeration capacity of Streams'. *U.S. Geol. Survey Circ. 542.* 1967.