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DISPERSION MODELLING IN RIVERS FOR WATER SOURCES PROTECTION. A CASE STUDY

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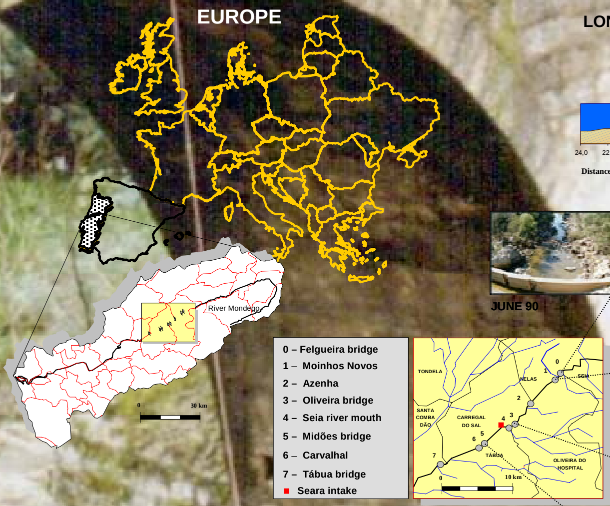
ABSTRACT

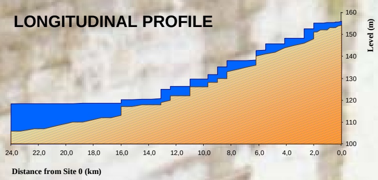
Judicious selection of mathematical models for application in a specific river basin management can mitigate prediction uncertainty. Therefore, intervention times will be established with better reliability and alarm systems could efficiently protect the aquatic ecosystems. A monitoring program was carried out using tracer injection (rhodamine WT) to assess the environmental impact of Urgeiriça mining waters in a Mondego river reach, between Caldas da Felgueira and Aguieira reservoir, where the Seara abstraction point is located. Parameters estimation for the *in situ* dispersion river water behaviour characterisation and performance evaluation of different numerical techniques when applied to river water dispersion modelling were the main purposes of this research work. For flow discharge values of 40 and 140 m^3s^{-1}, longitudinal dispersion coefficients average values are 35 and 60 m^2s^{-1}. The recovered rhodamine mass ranges from 55 to 65% of the total injected mass at all sampling sites.

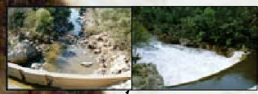
STUDY AREA

The study area occupies the medium part of Mondego river basin, located in the central region of Portugal. The drainage area is 6670 km² and the annual mean rainfall is between 1000 and 1200 mm. The river reach considered in this work begins downstream Caldas da Felgueira bridge and ends at Tábua bridge, in a distance of approximately 24 km. The water is intensively used for hydropower generation, domestic and industrial water supply and agricultural irrigation.

A monitoring program was carried out using tracer injection (rhodamine WT) to evaluate the in situ dispersion river water behaviour under three different flow regimes: flood (140 m^3s^{-1}), dry-weather (0,74 m^3s^{-1}) and frequent (40 m^3s^{-1}) conditions. Seven sampling sites were considered, being the site 0 (Caldas da Felgueira bridge) the upstream dye tracer injection point.







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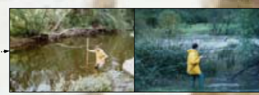

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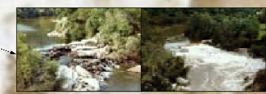

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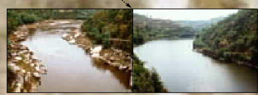

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METHODS

Trace experiments

The dye tracer used in this study was rhodamine WT. For concentrations measurements a "Turner Designs" fluorometre was used. The dye tracer injected mass recovered at each sampling sites allows to assess the importance of physical and biochemical processes by quantification of precipitation, sorption, retention and assimilation losses.

RHODAMINE SPREAD AFTER THE INJECTION AT SITE 0

Models description

Duflow Model

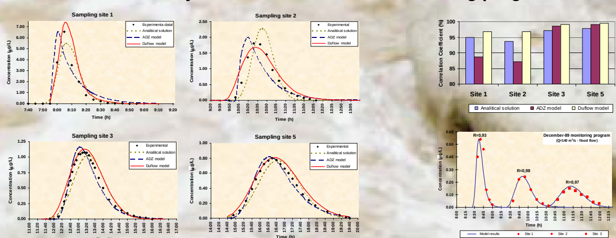
The hydrodynamic model is based on the one-dimensional partial differential equation that describes non stationary flow in open channels (ICIM, 1992). The water quality part of this package, based on the one-dimensional transport equation describes the concentration of a constituent as function of time and space.

Aggregated Dead Zones (ADZ) model

The ADZ modelling recent approach to modelling dispersion processes that provides accurate predictions of the time travel and spread moving downstream in a natural stream (Lees and Camacho, 1998). For advection/dispersion parameters estimation, ADZTOOL uses derived relationships from observed concentration-time data measured at two downstream locations.

RESULTS

***Duflow* and *ADZ* models were applied in order to assess numerical techniques performance reproducing the observed river dispersion behaviour. A good agreement between experimental concentration-time curves with model outputs and analytical solution results was obtained at the four sampling sites considered in the first injection of November 90 monitoring program.**

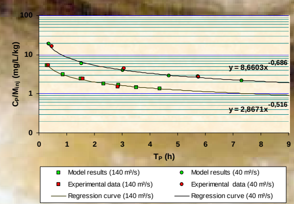


The correlation coefficients values calculated for the three worked models have shown a relatively better performance of *Duflow model,* that has been validated using experimental data from December-89 monitoring program.

Experimental longitudinal dispersion coefficients were calculated from concentration-time curves at consecutive sampling sites (Chapra, 1997). It is apparent little differences between this longitudinal dispersion coefficients and the values adopted for Duflow model calibration.

MONITORING PROGRAM	REACH	MEAN VELOCITY (ms^{-1})			TRAVEL TIME (h)			DISPERSION COEFFICIENT (m^2s^{-1})			RECOVERED MASS
		EXPER.	ADZ	DUFLOW	EXPER.	ADZ	DUFLOW	EXPER.	ADZ	DUFLOW	(%)
3 rd. (Nov.-90)	E 1 – E 2	0.526	0.548	Var.	2:37	2:31	2:35	14	43	10	57
	E 2 – E 3	0.497	0.502	Var.	2:41	2:39	2:41	51	25	45	56
	E 3 – E 5	0.473	0.473	Var.	3:21	3:28	3:19	37	36	35	55
	E 1 – E 3	0.511	0.524	Var.	5:18	5:10	5:16	34	33	-	-
	E 1 – E 5	0.497	0.504	Var.	8:38	8:38	8:35	35	35	-	-
1 st. (Dec.-89)	E 1 – E 2	1.105	1.114	Var.	1:14	1:14	1:14	52	59	40	62
	E 2 – E 3	0.949	0.954	Var.	1:24	1:24	1:24	61	61	70	62
	E 1 – E 3	1.023	1.030	Var.	2:38	2:38	2:38	58	61	-	-

In practice, river water dispersion characteristics can be evaluated from the peak concentration decrease with dye spread travel time variation (Hubbard et al., 1982). After initial tracer and river water mixing, the ratio – peak concentration (C_p)/total injected tracer mass (M_{inj}) – decreases with a power function of its travel times.



CONCLUSIONS

☞ One-dimensional mathematical modelling revealed to be a powerful and accurate tool to solve pollutant transport problems in river systems with a dispersion behaviour similar to the studied river reach, even under different flow regimes.

☞ Duflow model results showed the best agreement with experimental data, allowing a reasonable support for impact assessment of different discharges scenarios in the river water quality.

☞ For similar studies, dye tracer mass calculation has to consider an initial average loss near 40 %. In this conditions, the conservative substance maximum concentrations at Seara abstraction point are 2,2 and 1,5 mg/L/kg of discharged pollutant, for flow discharge values of 40 and 140 m^3s^{-1}, respectively. Longitudinal dispersion coefficients average values are 35 and 60 m^2s^{-1}.

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