Catena 170 (2018) 283–289

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Predictive scenarios for surface water quality simulation - A watershed case study

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A R T I C L E I N F O

Keywords:
Águeda River
Basin
Fresh water
Portugal-Spain
Qual2Kw
Self-depuration

A B S T R A C T

Surface water is exposed to contaminants which change the natural hydrological parameters and consequent contaminant dispersion. Water self-depuration is an ecological process aiming to restore the natural watercourse balance, which depends on the quality and quantity of topical and diffuse contributions. The main goal of this research is the evaluation of surface water quality in the Águeda River (Portugal-Spain transboundary watershed) and its self-depuration ability considering different predicted scenarios. Biochemical oxygen demand (BOD_5), dissolved oxygen (DO), dry residue, Ptotal, Ntotal, pH, temperature and microbiological parameters were analyzed, in thirty-six surface water samples.

Simulation of different quality scenarios was undertaken using Qual2Kw software and the river's self-depuration ability discussed. The obtained model's calibration achieved a score of 95% confidence interval, for almost analyzed parameters. The calibrated model was used for two prediction scenario construction. The first one, intending to assess the influence of topical contaminated discharge and the second one, aiming to evaluate the influence of minimum flow rates, representing an extremely dry year. The two considered scenarios revealed that self-depuration capacity is more affected by the presence of minimum flow rates than topical discharges, attesting a large potential for self-depuration along the Águeda River.

1. Introduction

Stream water quality is regulated by a complex suite of anthropogenic activities and natural processes, which could be directly or indirectly influenced by surface activities (e.g., Pratt and Chang, 2012; Ai et al., 2015). Watershed characteristics are also core factors in affecting stream water quality, as related to the importance of spatial features as causes or moderators of observed instream conditions (Johnson et al., 1997).

Variations in watershed characteristics and stream inflows often result in variations of hydrological conditions, thereby altering contaminant production, tape drive, and its delivery into streams (Xiao and Ji, 2007). As a result, watershed characteristics and stream inflows have been increasingly considered as factors affecting water quality in a variety of environments and different scales (e.g., Lecomte et al., 2009; Sullivan et al., 2010; Zhou et al., 2012; Antunes et al., 2016).

Exploring the relationship between watershed characteristics and seasonal variability of stream water contaminants has a considerable importance for watershed management. Seasonal variations of precipitation and surface runoff have a strong effect on flow rates and hence on the concentration of contaminants in the stream water (Vega et al., 1998).

The ability to predict the transport of contaminants in open channels (streams) is a major topic in many environmental projects, ranging from the accidental release of pollutants to the transport of non-point sources (Abderrezzak et al., 2015). Solute transport is controlled by a suite of hydraulic and geochemical processes, such as mixing, exchange with storage zones and biogeochemical reactions.

Water quality models are useful tools for determining contaminant plume behavior and impacts on water quality. Simulated scenarios are especially useful for accessing multiple possibilities and proactively developing response plans for rapid and appropriate actions if a contaminant event occurred (e.g., Henderson-Sellers, 1991; DiGiano and Grayman, 2014). Water quality models can be used to simulate hydrodynamics, heat transfer, and water quality processes in watersheds in order to predict the fate and transport of water constituents or contaminants. The models simulate contaminant concentrations and their spatial distribution together with natural water physical-chemical parameters, based on analytical or numerical procedures (Jeznach et al., 2016).

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https://doi.org/10.1016/j.catena.2018.06.021
Received 26 February 2018; Received in revised form 27 May 2018; Accepted 22 June 2018
0341-8162/

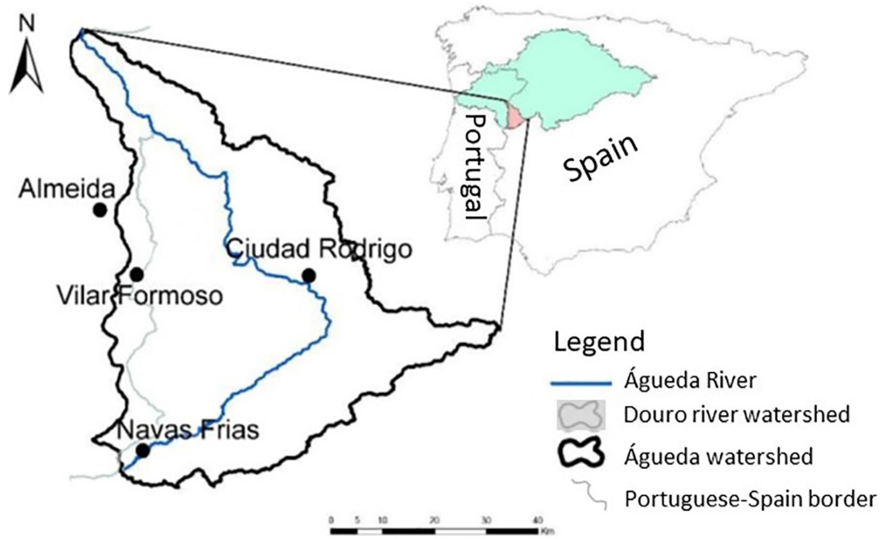

Fig. 1. Geographical setting of the Águeda transboundary watershed.

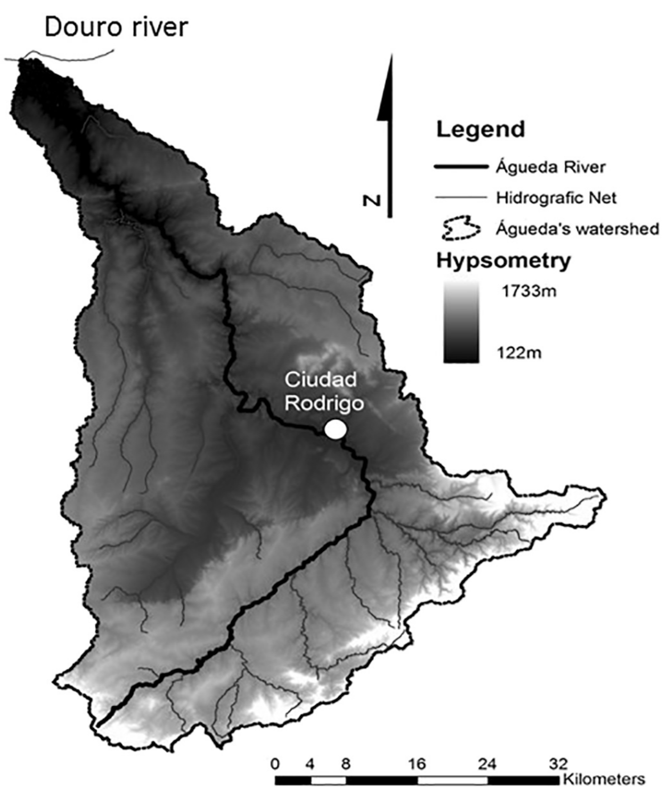

Fig. 2. Hypsometric map of the Águeda watershed.

A contaminant may enter in the watercourse as a topical or diffuse contribution. Topical contaminant sources are inputs occurring at a single location and may include inflows, such as those from a tributary or an accidental contaminant spill (Jeznach et al., 2016). Diffuse sources of contaminants can include surface contributions from a watershed, subsurface flow or atmospheric inputs. Diffuse pollution in agricultural watersheds is often significant sources of nutrients in the watercourse with considerable effects on water quality (e.g., Sharpley et al., 1994; Vorosmarty et al., 2007; Smith et al., 2017).

This case study introduces a framework based in water quality models to a better understanding of potential contaminant transport in surface water and to work as a tool for the development of appropriate emergency response and remediation actions, in a transboundary watershed (Portugal and Spain). The main objectives are: (1) characterize the Águeda river's spatial self-depuration ability; (2) simulate two different quality scenarios under the influence of a contaminant accidental topical discharge and a minimum flow rate condition (extremely dry year).

2. Study area and data

The Águeda transboundary watershed is in the central west of the Iberian Peninsula, extended between Portugal and Spain, and including the Spanish provinces of Salamanca and Cáceres (2290 km^2) and the Portuguese municipality of Guarda (310 km^2), with a total area of 2600 km^2 (Fig. 1). The watershed covers 79 local municipalities and a population of 49,000 inhabitants, with Ciudad Rodrigo (Spain; 13,800 inhabitants) as the most significant urban area. The agriculture is the dominant activity (Albuquerque et al., 2013).

The Águeda River is a tributary of the Douro River, with about 144 km long (Fig. 1) and materializes the natural border between Spain and Portugal. Water flows heading north (Douro River), with a general SW–NE to S–N runoff direction and altitude varying between 1733 m (south) and 122 m (north) (Fig. 2). Three geomorphological units can be identified: a) southern steep area (slope $^{>}$18%), corresponding mainly to granitic rocks and to the highest hydrographic network's density; 2) central flat zone, constituted by sedimentary materials, and occupied mainly by agricultural activities; 3) northern zone of higher altitude, downstream the river catchment, with dominantly metamorphic rocks (Fig. 2). Almost the area is occupied by the Tertiary Ciudad Rodrigo's sedimentary aquifer (Instituto Geográfico Nacional, 2009).