Integrated ecological modelling for water management in the urbanized area of the Cuenca River basin (Ecuador)

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Abstract: Efforts to improve the ecological status of water bodies in urbanized areas worldwide have been made either in isolated form or by means of integrated measures. In this study, we implemented a scenario analysis to restore the ecological water quality in the Cuenca River (Ecuador). For this analysis, an integrated urban wastewater system model was linked with ecological models. The ecological status of the waterways was evaluated with the Andean Biotic Index, which was predicted using generalized linear models. Four scenarios were analyzed. In these scenarios, the inclusion of a new wastewater treatment plant (WWTP) with activated sludge technology to remove carbon, or carbon and nitrogen, as well as the addition of retention tanks before the discharges of combined sewer overflows were assessed. The new WWTP with carbon and nitrogen removal would bring a better restoration. The retention tanks would help to enhance the ecological status of the rivers during rainy seasons. The integrated model implemented in this study was shown to be an essential tool to support decisions in the Cuenca River basin management.

Keywords: Cuenca River basin; integrated ecological modelling; River Water Quality Model No. 1 (RWQM1).

1. Introduction

The growth of urbanized areas around the world has increased the pressure on their nearby aquatic ecosystems. In particular, the strongest pressures originate from the wastewater and runoff during summer rain events, disturbing the ecological equilibrium of the receiving water body. This disturbance affects both the chemical composition of the water and the biotic structure [1].

To date, stakeholders have implemented isolated or integrated measures to enhance the water quality of the streams. In the case of municipal water management, a good planning tool for this optimization is the implementation of an integrated urban water system (IUWS) model that includes WWTPs, sewage networks and receiving water. Since 1984, the Water Supply and Wastewater Management Municipal Company ETAPA-EP has been working on improving the water quality status of the Cuenca River (located in the southern Andes of Ecuador). These efforts have been developed without a prediction of the possible results. Although the water quality has improved, the biological water quality varies between deficient and bad in most of the stretches of the urban area of the Cuenca River and its tributaries during the dry season; a quality that changes from moderate to good during the rainy season [2].

We aimed to develop and to validate an integrated ecological model (IEM) for the analysis of possible scenarios to be applied to river restoration and management. In this regard, the IEM incorporated four models: (1) a river model used to predict the

physicochemical water quality in watercourses; (2) an activated-sludge wastewater treatment plant model; (3) a sewer model that generates combined sewer overflows; and (4) an ecological model to assess the ecological river water quality. This framework was applied to analyze potential measures in the restoration of the Cuenca River.

2. Methodology

The study considered 43 sampling sites located in the city of Cuenca and nearby areas. From these sites, 27 were sampled during the dry season in July 2015, while 35 sites were sampled during the rainy season in March 2016. At each sampling site, environmental (physicochemical and hydro-morphological) conditions were recorded and biological (macroinvertebrates) samples were collected. Furthermore, at each sampling site, the Andean Biotic Index (ABI) was calculated to assess the water quality.

For the development of the IUWS model, we used as base the River Water Quality Model No.1 (RWQM1) [3] implemented in the WEST (www.mikepoweredbydhi.com) software. The following physicochemical variables were calibrated and validated during dry and rainy seasons: dissolved oxygen, COD, BOD_5, ammonium, nitrite, nitrate, phosphate (PO_4), average water depth and flow velocity. After the calibration and validation of the RWQM1, the results were linked to the ecological models developed by [2]. Four scenarios to improve the ecological water quality were analyzed, two for the dry season and two for the rainy season. These scenarios included the discharges from the current Ucubamba WWTP, a new WWTP with activated sludge technology and retention tanks located before the discharges of the combined sewer overflows (CSOs). For the new WWTP two possible options were studied, carbon removal only and carbon and nitrogen removal.

3. Results

The four scenarios applied to restore the ecological water quality in the Cuenca River system demonstrated that the all proposed measures would help to enhance the water quality in the urbanized area of the Cuenca River. With the implementation of a new WWTP, the benefits in the improvement of the ABI would be most significant during the dry season, with either carbon removal or carbon and nitrogen removal technologies. However, the carbon and nitrogen removal technology would bring a higher restoration of the ecological status of the Cuenca River during both seasons, due to the increased nitrogen removal. The retention tanks before the discharges of CSOs would also improve the ecological water quality during rainy seasons.

The scenarios analyzed in this research would enable stakeholders to gain insight prior to implementing measures to improve the water quality conditions of the Cuenca River system. In order to accomplish this, the implementation of the new WWTP is a priority for this purpose. Finally, similar applications could be replicated in other basins to analyze the impact of different measures on the ecological water quality.

References

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