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MANAGEMENT OF WASTEWATER TREATMENT PLANTS – A STATISTICAL APPROACH

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Abstract

The progressive deterioration of water resources and the large amount of polluted water generated in modern societies give Wastewater Treatment (WWT) processes a fundamental importance in water prevention and control. Inside a biological Wastewater Treatment Plant (WWTP), the activated sludge process is the most commonly used technology to remove organic pollutants from wastewater. This most cost-effective technology is very flexible and can be adapted to different kinds of wastewater. Therefore, it is very important to understand and to model the management processes involved that can lead to benefits for the overall WWTP, in particular in cost-effectiveness. In this work the discussion focuses on the dynamic monitoring procedure based on the statistical modeling approach, in order to quantify and to characterize significant statistical patterns of interaction between wastewater flows, hydro-meteorological variables (such as rainfall), and physicochemical variables. Activated sludge processes (ASPs) within wastewater treatment plants are commonly operated conservatively, aiming to maintain the healthy operation of the plant in the presence of varying plant loads. While the primary aim of wastewater treatment systems is to provide plant effluent of a suitable quality, this must be achieved in the presence of both physicochemical and financial restrictions on plant operation. Operating costs, in particular energy costs, associated with, for example, process aeration, are driven up by the inclusion of 'safety margins'.

A statistical exploratory analysis, calibration models and linear models were performed in order to obtain an accurate prediction and forecast of the relevant predictors (wastewater effluent variables) in the flows' behavior and which have the greatest impact on cost reduction. The statistical modeling procedure was applied to a set of nine Wastewater Treatment Plants located in the Northwest region of Portugal (five in rural regions and four in urban ones), and the dataset consists of monthly measurements during a period of two years, from January 2015 to December 2016. By accommodating the well-known seasonal regimes of dry and wet seasons, the statistical results will provide a better representation of the plants' real situation in order to design an efficient management process.

Keywords: Wastewater flows, physicochemical variables, seasonality, costs, correlations, linear models.

Tema: 2 - Água e energia

1. INTRODUCTION

Monitoring and management of water resources has been a special target of public policies, including large investments in both infrastructure and water quality monitoring networks. Wastewater Treatment Plants (WWTPs) have been the territorial units of excellence for water quality monitoring, both for environmental systems associated with them and the economic and social geography accompanying them.

A Wastewater Treatment Plant (WWTP) corresponds to an infrastructure of extreme importance and a solution for the decontamination of multiples watercourses to where a large load of effluents is channeled daily by means of sewage networks. This kind of plant is usually located in the final section of a watercourse, and continuously receives the liquid waste directed through public sewage networks. These effluents are later on submitted to a treatment conducive to obtaining a final high-quality effluent (by removing biological, organic and chemical pollutants from water), and thus allowing its reuse or drainage into the ocean or into a river, and therefore preserving water resources and promoting public health.

Wastewater treatment is a process of intensive use of resources, mainly energy. Energy consumption represents a significant part of the operative costs of a wastewater treatment plant. It is known from literatures and from managing experience (Venkatesh and Brattebo, 2011, Elías-Maxil *et al.*, 2014) that in a conventional WWTP about 25% to 40% of the operating costs are ascribable to energy consumption. With the expected demographic increase and the restrictive trend in quality standards for effluent discharge, energy consumption tends to further increase if there are no changes in the processes.

Another important issue, mostly connected to management aspects, is the presence of infiltration surface rainwater in the sewer networks, which burden the inflow rate and dilute the organic load, and any anomalous hydrodynamic behaviour of the reactors (Panepinto *et al.*, 2016).

The main motivations of this work are environmental and economic. In this context, the objective of this study was to identify and characterize the WWTPs processes management, particularly the biological processes used in wastewater treatment (activated sludge systems) in order to estimate costs treatment (energy consumption, sludges and byproducts) with greater precision and to establish a better cost-effectiveness implementation.

2. DATASET AND METHODOLOGY

This study involved nine WWTPs located in the Northwest region of Portugal: five in rural regions and four in urban ones (Gonzaga, 2017). The dataset consists of monthly values that were observed during a period of two years (from January 2015 to December 2016).

The study focused on the analysis of four physicochemical variables present in the wastewater flows (that are tributary to the WWTPs) and two hydro-meteorological variables (rainfall (mm), number of days (by month) of rainfall occurrence). The physicochemical variables were VSS – Volatile Suspended Solids (mg/l), TSS – Total Suspended Solids

(mg/l), COD – Chemical Oxygen Demand ($\text{mg O}_2/\text{l}$), and BOD₅ –Biological Oxygen Demand ($\text{mg O}_2/\text{l}$).

The study also involved the analysis of wastewater flows tributaries to the WWTPs (m^3), and two economic variables (cost variables associated to the treatments): energy consumption KW/h (euros), sludges, and byproducts (euros).

Initially, an exploratory statistical data analysis is performed with the main objective of identifying and characterizing the WWTPs processes management, particularly the biological processes used in wastewater treatment (activated sludge systems). The final stage consists of estimating treatment costs (energy consumption, sludges, and byproducts) with greater precision and to establish a better cost-effectiveness implementation.

Processes based on statistical methods were developed to quantify and characterize the quality parameters variability of both the raw sewage and the primary effluent supplying the aeration reactors of most wastewater treatment plants (WWTPs). In particular, were applied several statistical techniques in order to identify significant statistical patterns of interaction between raw wastewater inflow and hydro-meteorological variables.

The main discussion focused on establishing analyses and statistical models (Costa and Gonçalves, 2012) in order to quantify and characterize integration patterns among wastewater flows tributaries to the WWTPs, the hydro-meteorological variables (such as rainfall), the physicochemical variables and cost variables associated to the treatments. Calibration models and linear models (Gonçalves and Alpuim, 2011) were established from an exploratory analysis of data aiming at estimating and predicting the dynamic monitoring procedures involved in these processes. These models integrated the seasonal behaviors throughout the year which have an enormous impact on the processes variations, considering the observed data in both dry and rainy seasons.

The modeling process considered two hydrological periods: dry season (July, August and September) and rainy season (January, February, March, April, May, June, October, November and December).

3. CONCLUSIONS

The application of mathematical and statistical modeling to wastewater treatment processes is a suitable tool for the technical and economic improvement of the operation efficiency involved in the system. With this study it is expected that the developed methodologies have an important contribution to management efficiency, in particular to energetic efficiency, sustainability of the treatment systems, and wastewater exploration.

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REFERENCES

Costa M., Gonçalves A.M. (2012). *Combining Statistical Methodologies in Water Quality Monitoring in a Hydrological Basin – Space and Time Approaches*. In Water Quality Monitoring and Assessment, ed. Kostas Voudouris and Dimitra Voutsas, 121-142. ISBN: 978-953-51-0486-5. InTech Published.

Elías-Maxil JA., Peter van der Hoek J., Hofman J., Rietveld L. (2014). Energy in the urban water cycle: actions to reduce the total expenditure of fossil fuels with emphasis on heat reclamation from urban water. *Renew Sustain Energy Rev* 30, 808-820.

Gonçalves A.M., Alpuim T. (2011). Water quality monitoring using cluster analysis and linear models. *Environmetrics* 22 (8), 933-945.

Gonzaga, A.S. (2017). *Análise Disruptiva dos Custos de Exploração numa Base Estatística. Relatório de Estágio, Licenciatura em Estatística Aplicada*, Universidade do Minho, Guimarães, 59p.

Hothorn T., Everitt B.S. (2014). *A handbook of statistical analysis using R*. 3th Ed. Chapman & Hall.

Panepinto D., Fiore, S., Zappone, M., Genon, G., Meucci L. (2016). Evaluation of the energy of a large wastewater treatment plant in Italy. *Applied Energy* 161, 404-411

Venkatesh G., Brattebo H. (2011). Energy consumption, costs and environmental impacts for urban cycle services: case study of Oslo (Norway). *Energy* 36, 792-800.