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Dynamic simulation for the requirements of oxygen about the Municipal Wastewater Treatment Plant - Case of Souk-Ahras/Algeria

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Abstract

Today, in Algeria, most wastewater treatment plants (WWTP) are of the biological activated sludge type. Generally, the urban effluents are forwarded to a basin where microorganisms in the form of activated sludge proliferate. To do their job, microorganisms (activated sludge) consume oxygen, which must be suitably supplied. Aeration for the purpose of supplying oxygen accounts for 50 to 80% of the energy expenditure of the plant. This research, conducted using GPS-X software and the model ASM1 of IWQ and using available data, aim is to model the process of oxygen transfer in the aeration basin at Souk-Ahras WWTP. The end result is to reduce the cost of energy at the plant, which is weighing down the finances of the management. Keywords: wastewater characterization, modeling, ASM1, IWQ, simulation, GPS-X, WWTP.

1. Introduction

The advent of more stringent environmental regulations relative to WWTP and discharge put more pressure on operators and decision makers to better manage and improve the reliability of their treatment plants.

The actual population of Souk-Ahras, northeast of Algeria, is 145 000 inhabitants and is expected to reach more than 180 000 in the next 10 years. Produced wastewater is being treated in a 20 years old, biological activated sludge based treatment plant with a nominal capacity of 30 000 m^3/d or 150.000 EP. Therefore, it is very important to evaluate the capacity of the plant for eventual upgrade. Also energy expenditure at the plant is relatively high and a lot of pressure is put on managers to reduce its cost.

Mathematical models are well suited to address these concerns and to develop better management and operation strategies. They cost little, can evaluate thousands ofscenarios, and pose no or minimum risk to the plant compared to other approaches such as real testing and stressing the plant.

This article is devoted to studying the WWTP at Souk-Ahras and in particular the aeration basin and the role of oxygen management in the process as shown in Figure 1. The study is carried out, in two parts, using GPS-X simulation software.

The following parts will be respectively devoted to the process of treatment by activated sludge which consists of two principal entities. On the one hand, the engine in which the incidental pollution is degraded and which is governed by primarily biological mechanisms related to the oxygen uptake. On the other hand, the clarifier from which the function is to separate water treated from the biomass and other particulate compounds, and for which the mechanisms coming into play, are primarily physical, presenting the advantage to be quickly accessible and thus to lend itself to a regulation on line carrying according to our study on: Concentration of oxygen dissolved in the basin of ventilation, concentration of activated sludge mixed liquor contained in this basin ventilation and crossing of flow effluent in basin ventilation,

2. Model ASM 1

The model used in this work is based on the Activated Sludge Model No.1 (ASM1) by Henze et al. (1987). This is the most popular mathematical description of biochemical processes in the reactors for nitrogen and chemical oxygen demand (COD) removal. It was adopted with two modifications: (i) the state variable describing the total alkalinity is not included, and (ii) inert particulate material from influent and from biomass decay are combined into a single variable (XI) since they are of minor interest (Figure 1). The resulting biodegradation model consists of 11 state variables and 20 parameters. The kinetic and stoichiometric parameter values considered are those defined for the simulation benchmark (Alex et al., 1999). The complete set of equations, parameters values, and influent conditions can be found on the European COST action 624 website.

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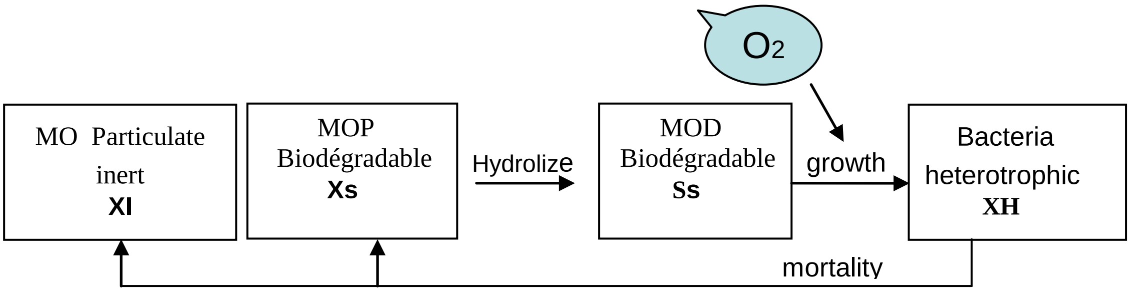

Figure 1: Concept describing the biological breakdown of the dissolved and Particulate organic matter in ASM1 (IWA; 1987)

3. Materiels et methodes

3.1. Presentation of WWTP Souk-Ahras

The WWTP of the town of Souk-Ahras is intended to treat domestic waste water before their discharge into the Medjerda River. Figure 2 presents a schematic representation of the plant. The actual capacity of the plant amounts to 30 000 m^3/d or 150.000 EP. The actual population of Souk-Ahras is 145 000 inhabitant. Therefore, it is very important to evaluate the capacity of the plant for eventual upgrade, which is another reason of upmost importance to operator and decision makers to conduct this work.

3.2. Presentation of the GPS-X

GPS-X is a software program specifically designed for the modelling and simulation of municipal and industrial wastewater treatment plants. GPS-X has an easy-to-use interface connected to an extensive library of simulation models. This greatly reduces the effort of carrying out simulation studies.

GPS-X can be used to improve capacity, operating efficiency and effluent quality by optimizing properly existing facilities. This can result in capital savings and lower operating costs.

3.3. Data input

To model the operation of a WWTP, it is imperative to have precise and specific data: physical description (volume of the works, flows, pumps, etc.), management (controls and automations, aeration, extractions of mud, etc.), and water quantity and quality to be treated. On this last point, the models often require data which are not directly accessible and for which there does not exist simple and standardized protocol of measurement. For example, the total concentration in DCO of the effluents is not sufficient, it must be broken up into 4 or 5 fractions according to their behaviour in the station (quickly and slowly biodegradable, soluble and particulate inert, biomasses).

3.4. calibration and validation of the model

Any modeling requires phases of parameter setting and checking of the model. The phase of Any modeling effort requires two phases of parameter calibration and validation. The calibration phase aims at optimizing manually or automatically the adjustment of certain variables so that simulated and observed values are as close as possible. The stage of validation aims at checking the quality of the model used on a different series of measurements not used during the calibration phase. The successive realization of the calibration-validation constitutes the stage of development of the model on a given site.

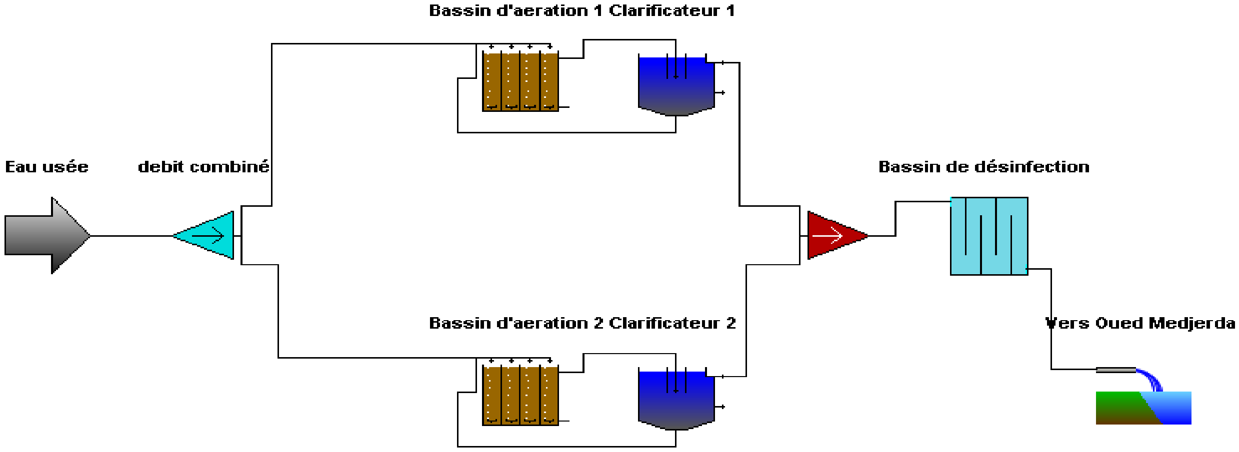

Figure 2 : Configuration of the WWTP

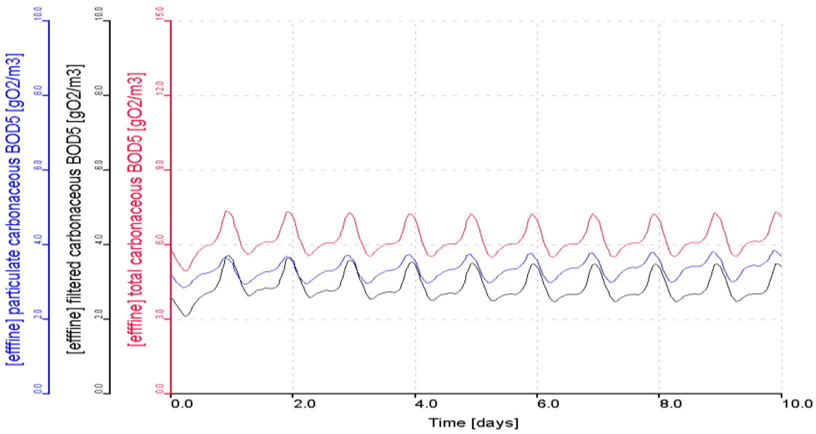

Figure 3*:* DBO5 and its fractions at exit of clarifier

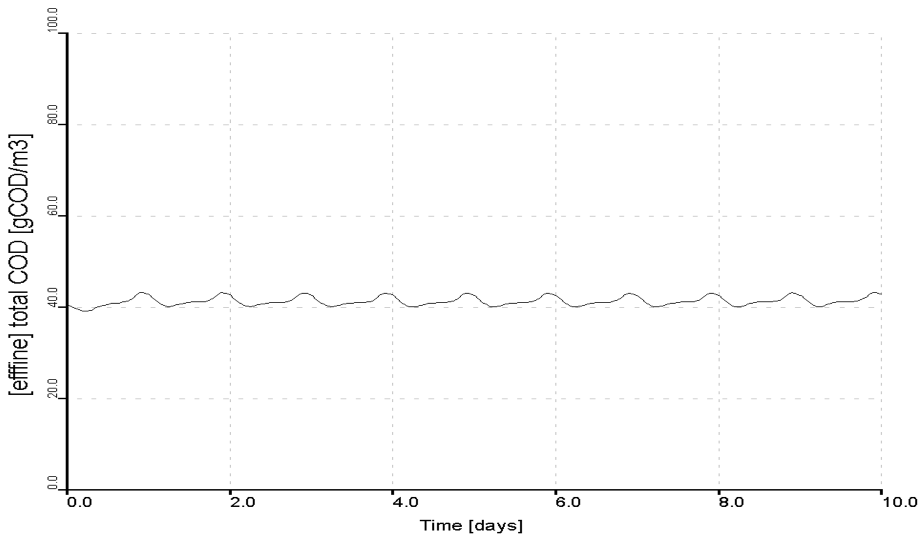

Figure 4: DCO at exit of the clarifier

➢ Oxygène Transfer in the aeration basin

The aeration basin is the key component of a WWTP. In the aeration basin one distinguishes several possible aeration systems, but the energy aspect of these structures or systems confers them a particular position. Indeed, the cost of aeration accounts for 50 to 80% (FNDAE, 2000) of the energy cost in an activated sludge based WWTP. That is why we undertook a series of simulations in order to minimize the operating costs.

The determination of the real oxygen needs (AOR) is based on the determination of transfer rate under standards conditions (SOTR). The latter is based on estimating the number of aeration equipments, the calculation of the volumetric output for each equipment, and the determination of the absorptive powers by the equipment. Having calculated the latter, we can carry out the estimation of the real yearly consumption of electrical energy for any system of aeration.

➢ Determination of AOR

Figure 5 represents the estimate of the real oxygen needs for continuous aeration under the conditions of the Souk-Ahras WWTP. The AOR is estimated on average at 2345 kg/d.
According to the simulation results, the calculation of the oxygen transfer rate under standard conditions is about 46 692 kg/d.

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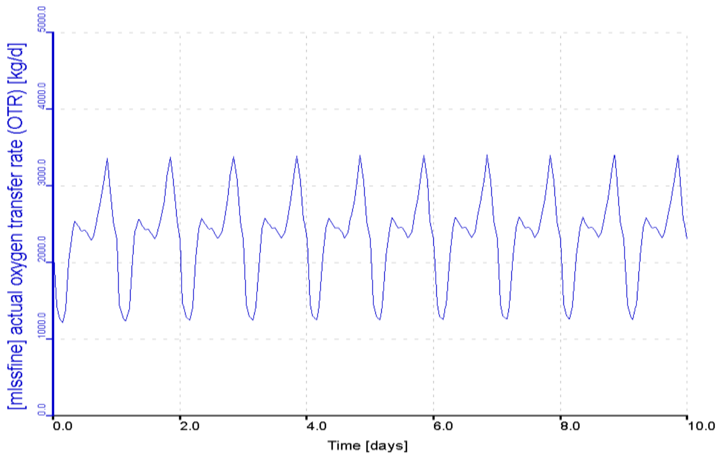

Figure 5 : The rate of transfer of current oxygen

- Determination of SOTR
- Energy of ventilation

The aeration energy is represented in Figure 8 with an average value of 1110 kW using an output efficiency of 50%. This energy is evaluated at 70.000 kW per month. The average consumption of energy in the WWTP is about 120.000 kW, which is very close to observed values. This is another indirect proof that our model simulates accurately the plant and can, therefore, be used for operation improvement and debottlenecking.

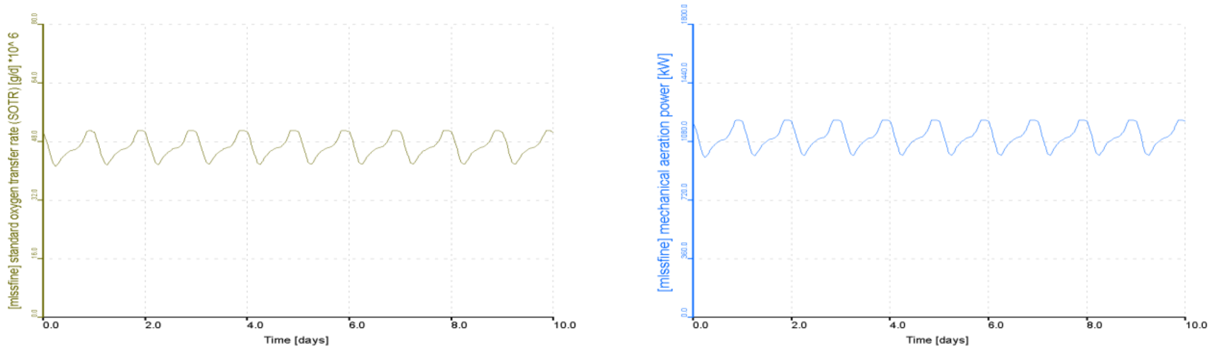

Figure 6 : Oxygen transfer rate under Standard conditions

Conclusions and prospects

A mathematical model can be used to simulate the operation of a WWTP. It can do so without wasting time and resulting cost of doing the same simulation on the real system with the plausible drawbacks. In any case, the user can specify entries, run simulations, exploit the results and judge their ability to address the problems the plant is facing. If necessary, he can modify the data and restart the process.

The model developed for the Souk-Ahras WWTP simulated well the process and estimated, with accuracy, energy needs of the plant. The model is under improvement to help reduce the high quantity of biosolids produced.

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