Utilization of informational systems to optimize the wastewater treatment plants efficiency

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Abstract:

Actuellement, quand les questions environnementales sont traitées avec beaucoup de responsabilité tant au niveau mondial que régional, le traitement des eaux usées est un sujet réel et d'un grand intérêt, qui doit être garantie de qualité des eaux rejetées dans les milieux aquatiques.

1. Introduction

Nowadays, when environmental problems are dealt with more responsibility in the world and also in Republic of Moldova, wastewater treatment is an issue of great interest, through which it must be ensured that the quality of waters discharged into aquatic environments are acceptable according to standards.

Treatment plants are a complex of buildings and installations, in which the wastewaters are subjected to technological processes of treatment that change their qualities, as to fulfil the prescribed conditions discharged into natural resources.

Traditionally, technological scheme of urban wastewater treatment coming from places equipped with centralised sewer systems contain two distinct streams: wastewater flow stream and sludge stream that formed in wastewater treatment processes.

Wastewater treatment is carried out in several steps, aiming to eliminate each of them a certain type of pollutants. In fact, existing treatment plants are meant to remove or reduce the concentrations of two categories of pollutants:

a) insoluble mineral and organic origin, expressed through the indicator of the level of pollution called "suspended solids – SS", and
b) the majority of organic soluble, which are characterized through the global indicator (equivalent in oxygen consumed for the oxidation of these substances) – chemical oxygen demand – COD, or biochemical oxygen demand – BOD, this being the part of organic pollutants, which can be removed from wastewater by biological way.

2. General characteristics of the wastewater treatment processes

Biological treatment is the process that is based on the use of microorganism's capacity to assimilate and mineralize dissolved organics in wastewater, which passed the first stage of treatment – mechanical treatment.

Depending on the bacteria involved in biological treatment, different aerobic processes take place in the presence of oxygen, used by aerobic bacteria to oxidize organic substances producing CO_2 and H_2O, while anaerobic processes take place in the absence of oxygen and are based on reducing the organic substances with the removal of other products (acids) and gas (CH_4, H_2S, H_2, N_2, CO_2).

Biological wastewater treatment is known as secondary treatment. It may be followed by a biological tertiary treatment, when conditions treated water discharge into natural sources require a more advanced level of treatment, than is possible in a classical mechanical biological treatment or when required and removing nitrogen compounds and phosphorus.

A typical scheme of aerobic biological treatment of activated sludge is shown in (fig. 1), which shows an activated sludge aeration tank that consumes biologically degradable pollutants from wastewater and after then is separated through gravity activated sludge in secondary settling.

Biological treatment achieved efficiency of 90 – 95 % in terms of reducing the concentration of suspended matter and below 70% in terms of reducing the concentration of organic substances expressed in BOD_5.

In the operation of the treatment plant, unwanted events may occur because of a succession of dysfunction, caused by a variety of parameters of different nature occurring in the process.

Treatment processes are special from other industrial processes in terms of the characteristics and operational objectives. The basic principles of industrial process control can be applied in wastewater treatment plants, but the characteristics of wastewater treatment plants require specific considerations in the design of control systems [4,10]. The complexity of physico-chemical-biological processes, in which they interact with a multitude of parameters of different nature and the limited number of parameters that can be manipulated, it is difficult to drive optimal treatment technology as a sum of unit processes that interact with each other.

It takes a real art to controlling biological treatment processes, based on the properties of activated sludge: the dose, age, sludge index, morphology, etc. There are about 18 indicators and parameters affecting/influencing the treatment efficiency in aeration basin and secondary settler. So, the specifics of these processes is to continuously variable seasonal, per diem and hourly wastewater flow and its characteristics, expressed by the values of parameters characteristic of pollution, the dimensions of the chemical and biological reactors as well as the interaction of wastewater – unit process - equipment are elements highlights the difficulty of the problem and automatic control of the process.

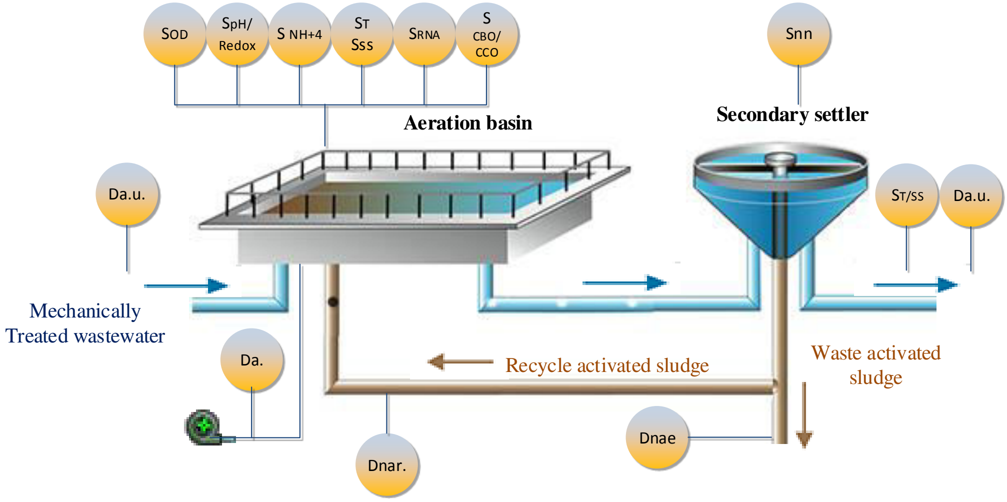

Figure 1. Typical scheme of biological wastewater treatment

S_{od} – sensor of dissolved oxygen; **$D_{a.u.}$** – wastewater flow meter; **;** **S_{pH}/R_{edox}** – sensor of pH (the concentration of hydrogen ions)**;** **S_{NH4}** – sensor of the ammonium concentration; **$S_{CBO/CCO}$** – sensor of the organical substances concentration **;** **$S_{T/SS}$** **-** sensor of suspended solids; **D_a** – air flow meter; **S_{RNA}** – sensor of breathing activated sludge; **Dnar** – recycle activated sludge meter; **D_{nae}** – waste activated sludge meter; **S_{nn}** – sensor of sludge level.

3. Control of wastewater treatment processes

Wastewater treatment processes are presented as a complex bio-chemical processes that compared to other similar industrial processes, have several distinct in terms of their both characteristics and operational objectives. The need for automation of these processes comes from their inability to maintain dynamic equilibrium in the presence of perturbations, which can be temporary, cyclical or periodic often being random. Direct or indirect disturbance on the wastewater treatment processes justify the implementation of automatic control systems, which tend to maintain equilibrium processes, which is very complicated or impossible for the human operator.

From the point of view of theory of the automatic control, a unit of wastewater treatment (biological) plant can be present as a "black box" with the following sets of inputs and outputs (fig. 2) [4]:

1. The input variables:
- The wastewater flow - Q;
- The level of pollution influent - xe;
- Chemical reagents used in the process - r;

- Heat / electrical power for maintaining the process.

2. output variables:

- Residual pollution level - x;
- Concentrations of nitrogen and phosphorus;
- The amount of waste sludge - Qn ex.

3. Perturbations - factors acting on the input variables (variation of the wastewater flow, its pollution levels, the temperature, the presence of toxic compounds) which forced deviation from state calibration.

4. The operating variables are those that can be maintained in spite of perturbations in state of calibration. In most cases, the operating variable is the amount of recycled sludge - b, the speed of movement of multi-phase media, the concentration of organic substances and other.

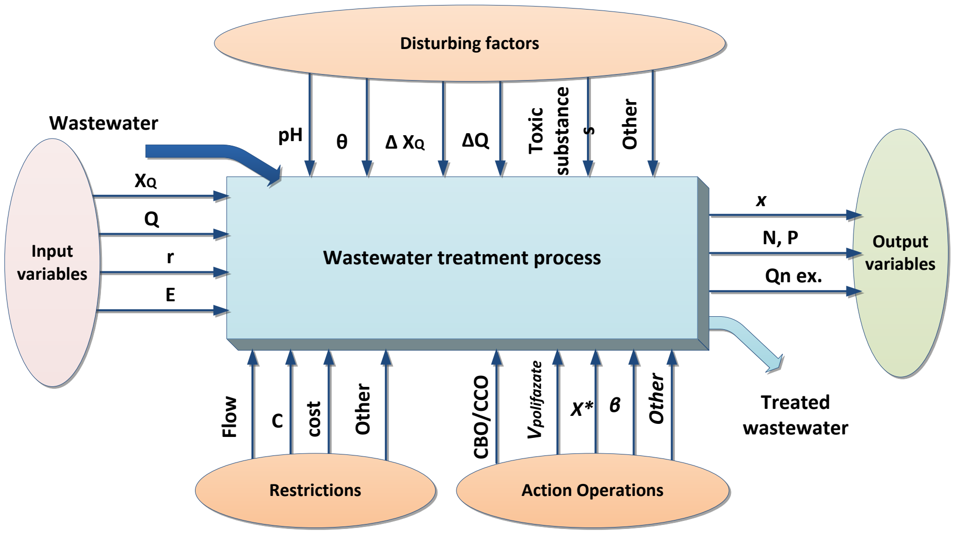

Figure 2. Scheme of the control of biological wastewater treatment plant

The restrictions shown in case of biological treatment of the limit of oxygen concentration in the aeration tank, the concentration of nitrogen and phosphorus, as well as in the other reactive consumption.

In actual applications of control and automation processes in maintaining balance is often achieved regulators acting under proportional - integral - differential (PID) classic (fig. 3), because it presents an effective solution and it is easy to implement. Firstly, being designed for linear systems time invariant controller / PID algorithm has developed, allowing engineers to control and complex dynamic systems. PID algorithms are made in discrete form the microcontroller's control processes fast enough reaction time of less than hundredths of a second. On the other hand, in reality, all systems have nonlinear components, which presents challenges in using control classic PID. First, the adjustment pattern have to match exactly the process and have to be periodically adjusted when the variation of the system in time. This procedure of adjusting PID is sophisticated and requires an appropriate approach [5,6,7].

The appearance of the theory of fuzzy sets and development of electronic systems have paved the way for application in automatic control systems. In this case, the classic PID control algorithms are replaced by a set of rules of type ***IF (premise) THEN (conclusion/share).*** Therefore, obtain a heuristic algorithm, which can take into account the human factor in process management experience, which is very important for complex processes.

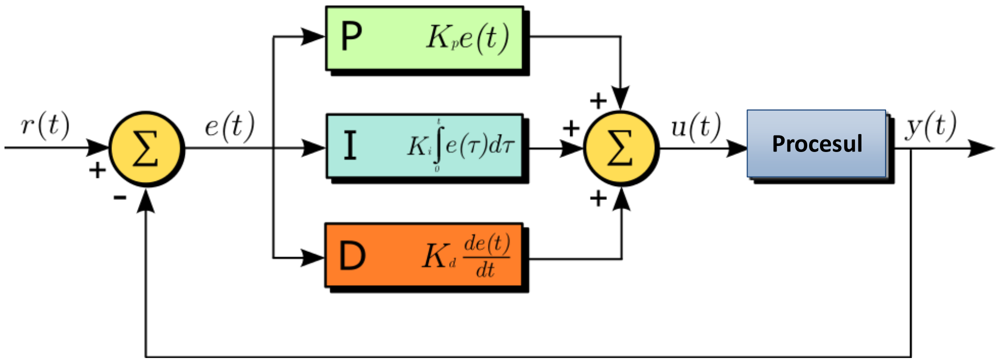

Figure 3. The structure of PID controller classic

The application of the fuzzy theory for automatic adjustment systems may be in several ways, the most common of which are [4]:

- fuzzy direct control of the process;
- supervising fuzzy PID regulators classic;
- adapting fuzzy PID controllers classical parameters.

The analysis of several sources [4, 9] including own experience, we proposed application fuzzy control on the processes that are easier to design, implementation of the human operator experience and the other - allows an opening of joint the other approach.

We propose the following direct fuzzy control structure shown in (fig. 4), is made up of the following components.

- **Module of fuzzification** of the input variables, the variables process. The imput variables were real values, which must be transformed into fuzzy values, their need to be assigned fuzzy values, which are prerequisites. Therefore, this premise will determine which rule must be activated with the degree of membership from each rule. This degree depends on how much the input value and the preconditions of the rules correspond to each other.

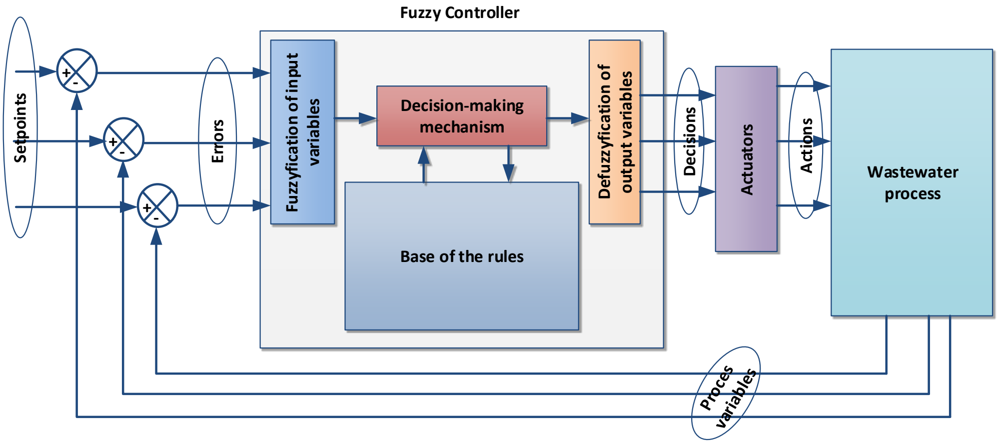

Figure 4. The structure of Fuzzy control of the wastewater treatment process

- **The rules base**. This component is made up of the whole set of rules like ***"IF (premise) THEN (conclusion / share)"***. The premises are introduced the values of the input variables, so as to be able to decide, which rule can be activated and which not, then in what way should be used. The result/outputs of the rules activated are merged and transmitted to the user interface of the defuzzification. As a rule, experts in problems of management of those processes, taking into account the experience of the human operator, create this base.

- **Decision-making module/inference** carried out based on the data fuzzificate assessment base rules in order to obtain the decision/conclusion fuzzy.

- **Defuzzification module.** Decision fuzzy obtained by the inference has a complex shape because it reflects a combination of multitudes fuzzy with limited degrees of belonging. The destination of this module is to form a single real value, including the output fuzzy.

4. Innovative Aspect and Main Advantages

The Implementation of Supervisory Control and Data Acquisition (SCADA) system, in the integrated water management contributes to efficient management of this important resource and increasing performance operating water distribution systems and treatment wastewater, while maintaining an accessible price to end users. Remote Terminal Units (RTU) are dedicated to ensure monitoring of water parameters and associated processes, achieving the better control in the system, eliminating the frequent and long-distance movements of technical service personal. Real-time information and calculations performed by the Centre for Control gives operators the opportunity to make a better plan of operation. The advantages of automation are; increasing the functioning of productivity, improving levels of performance and quality of treated water, increasing efficiency and competitiveness, improvement of data acquisition.

5. Areas of Application

Inside the wastewater treatment plant will be located control centre, which will shelter the equipment dispatch and operator workstations. The SCADA system shall comply fully with these requirements for electrical work. Central Dispatch will be provided with all necessary elements (hardware and software) in order to ensure in the future, transmission of information and commands to and from a dispatch. The SCADA system will provide online data history for all entrances / exits to / from the system. All operation and alarm signals emitted by the system will be sent to the dispatcher. Each equipment failure will lead to an alarm in the SCADA system. Monitoring parameters in treatment processes is an essential activity in wastewater treatment stations; it is closely linked to environmental monitoring in general. Its purpose is to monitor the degree of compliance with legislation, monitoring water quality parameters at the exit of the wastewater treatment plant and to monitor the functioning and effectiveness of their treatment process, monitoring the treatment process parameters. Monitoring treatment process parameters is the basis for optimization of treatment. It leads also to minimize losses, planning maintenance, repair and energy savings by reducing losses.

Conclusions

The treatment processes are distinguished from other industrial processes in terms of the characteristics and objectives operational, because the operation of the treatment plant may appear undesirable events. The basic principles of industrial process control can be applied in wastewater treatment plants, but the characteristics of wastewater treatment plants require specific considerations in the design of control systems. Due to the complexity of physical-chemical-biological, which interact a multitude of different parameters and the limited number of parameters that can be manipulated, it is difficult to lead optimally these processes. It has been proposed the fuzzy control method, the advantage is to provide a heuristic algorithm driving the process, which can take into account the human operator's experience in managing these processes, with the performance of PID controllers classic.

Monitoring parameters in the treatment processes is an essential activity in wastewater treatment plants, it is closely linked to environmental monitoring in general. Its purpose is to track the degree of compliance with the legislation by monitoring the parameters of water quality at the exit of the treatment plant and to follow up the performance and efficiency wastewater treatment by monitoring parameters treatment processes.

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