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Network Modelling of Biological Wastewater Treatment System of Paint Manufacture

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Abstract: The study discusses the technological complex of Biological wastewater Treatment (BOT) of paint manufacture. Based on the review of the main modeling methods of discrete-continuous chemical processes, it substantiates expediency of using the theory of Petri Nets (PN) for modeling the process of wastewater treatment in paint manufacture. It is proposed to use a modification of Petri nets which is focused on modeling and analysis of discrete-continuous chemical processes by prioritizing transitions, timing marks in positions and transitions. A model in the form of Modified Petri Nets (MPN) is designed. A software package to control the process for wastewater treatment is designed by means of SCADA TRACE MODE.

Key words: Modified Petri nets, wastewater treatment of paint manufacture, modeled systems, chemical-engineering system, computer modeling

INTRODUCTION

Modern process systems of wastewater treatment have a complex multi-layered structure, therefore, they can be considered as complex cybernetic systems. When studying them, the strategy of system analysis is used. Given the task complexity of modeling and analysis of such systems, it is necessary to apply modern methods of mathematical and computer modeling.

MATERIALS AND METHODS

In solving the problems set up in the study, the methods of systems analysis, computer modeling, Petri nets theory, graph theory were used.

Theory: Wastewater of paint contains soluble organic compounds such as phenol, formaldehyde, alcohols, ethers, solvents; therefore, direct drain of waste water from plants can cause severe environmental pollution due to their high toxicity. The existing chemical and physicochemical methods for purifying waste water from these compounds are expensive, ineffective and time-consuming. The most affordable, economically viable, quite effective is biochemical method of water treatment. However, the biochemical wastewater treatment process has a number of specific requirements, namely:

- The balance of the ingredients of treated wastewater for the main biogenic elements (carbon: nitrogen: phosphorus)
- Lack of intensive pulsation components of volume flow of waste water supplied to the bio-oxidant
- Prohibition of significant deviations from the optimal values of the technological parameters such as pH, temperature, oxygen conditions, the ratio of easily and difficult to digest organic matter, etc.

Even a slight deviation of process parameters from the optimal values results in a long period of adaptation of bio-oxidant microbial flora which affects the quality of treated wastewater badly. Therefore, in the operation of technological schemes of biochemical waste water treatment it is necessary to provide preventive actions against the negative factors to avoid a long period of cleaning system breakdown. In developing and implementing of such actions, various ways of processes intensification, methods of system analysis and mathematical modeling are used. Modern treatment facilities of large chemical enterprises are structurally complex systems, therefore, they may be considered as complex cybernetic systems (Fesina and Savadur, 2014). The efficiency of such systems can be achieved by using modern methods of information processing, using the methods of complex objects system analysis based on the mathematical description of the process (Hunt *et al*., 2012).

In accordance with the principles of system analysis, industrial wastewater treatment plant is a chemical and engineering system which includes a set of interrelated material, thermal and information flow units, each having

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a hierarchical structure (Motameni *et al*., 2008). Biological waste water treatment can be divided into interconnected subsystems characterized by a hierarchical structure. Management tasks at each level of the production hierarchy are different but the general objective is wastewater treatment to standard indicators or to provide recycling water supply level. A main area of studying complex systems which wastewater treatment represents is informational approach that is based on mathematical modeling of the object (Huilinir *et al*., 2011). Modeling and computer experiments with model-replacement of an object are an effective means to create management systems, to consider the object's behavior in emergency situations, to evaluate its structure and control rules, as well as to take into account the stochastic nature of disturbances (Haroonabadi *et al*., 2008; Ruiz *et al*., 2011).

There are two approaches to the modeling of real objects. In the first approach, the object is represented as a dynamic system with a continuous variable. This approach is widely used in modeling chemical and engineering systems with continuous organization of processes (Pitter, 1976; Buswell and Mueller, 1952) provided its stationarity and the invariableness of physical and chemical parameters. In the second approach, the object is represented as a dynamic system with discrete events. These include manufacturing systems, assembly lines, computer networks.

Dynamic system with discrete events class also includes discrete-continuous chemical and engineering systems. Solving the problem of managing such discrete dynamical systems requires the use of special mathematical methods. Traditionally, for this purpose, the state machine approach, logical-linguistic and simulation modeling are used as well as the theory of graphs and networks, PN. Comparative analysis as the primary unit of mathematical modeling helps to select the PN theory. PN enables to simulate discrete parallel asynchronous processes (Zhou and Li, 2010) to get a graphical representation of the network, to describe the system at different abstraction levels, to present the system hierarchy (Barzegar and Motameni, 2011) to analyze models using modern software packages.

RESULTS AND DISCUSSION

Applying the methods of system analysis enables to develop a control system of treatment plants of biological wastewater treatment of paint manufacure (Fig. 1) which provides for the construction of a mathematical model based on the PN. Figure 1 shows that, 1 flotator, 2 intermediate container, 3 anaerobic reactors, 4-1st stage

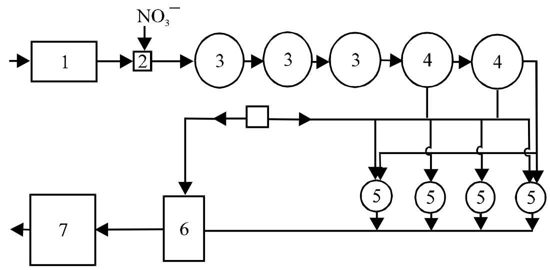


Fig. 1: The technological scheme of biological wastewater treatment system of paint manufactur

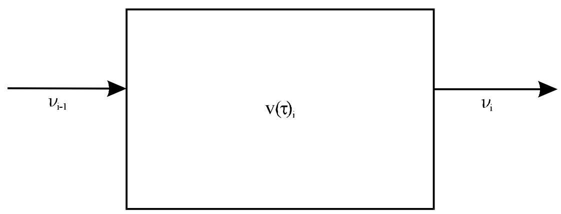
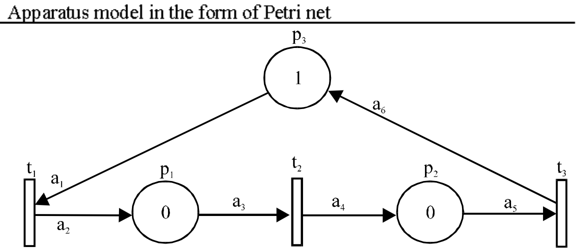
aerobic bioreactor, 5-2nd stage aerobic bioreactors, 6 zooreactor, 7 storage of treated water and 8 blower. To describe the system, we propose to use N-schemes, based on the mathematical apparatus of Petri nets whose advantage is possible representation of the network model both in analytical form, automating the process of analysis and in graphical form providing visualization of the model developed.

When analyzing biochemical and engineering flow diagrams one should consider the main limitation of the N-scheme formalism which consists in the fact that they do not account for the time characteristics of the simulated systems, since the enabling time of the transition is considered to be zero. Given these conditions, we have proposed the modified Petri net. MPN is Petri net in the form of:

$$C \leq P, T, I, O, M, L, \tau_1, \tau_2>$$

where, T $\{t_j\}$ is the finite non-empty set of symbols called transitions are measured depending on the number of conventional product portions with a continuous feeding to apparatus in the process flow; $P = \{p_i\}$ is the finite non-empty set of symbols called positions. In our case it is a set of process flow devices; I: $PxT\rightarrow \{0, 1\}$ is the input function which for each t_i transition gives the set its position $p_i \in I(t_j)$; O $PxT\rightarrow \{0, 1\}$ is the output function which reflects a transition to the set of output positions $p_i \in O(t_j)$; M: $P\rightarrow \{1, 2, 3, ...\}$ is the marking of net which assigns a non-negative integer to each position which is equal to the number of marking in a given position which varies during the operation of the net; τ_1: $T \rightarrow N$ and τ_2 : $P\rightarrow N$ is the functions which determine the delay time when enabling transition and the delay time in the position. Thus, for each transition it is possible to determine the set of input position I (t_j) and the output position O (t_j) as:

Table 1: The state of individual apparatus (positions) for the chemical and engineering production in analytical and graphical form

Process scheme of apparatus	Apparatus model in the form of Petri net
	
where, v_{i-1}, v_i is volume flow rate at entrance and exit of ith apparatus (m^3/sec); $V(\tau)_i$, V_{0i} is full and current volume of ith apparatus (m^3). $I(t_i) = \nu_{i-1}\Delta\tau$, $O(t_i) = \nu_i\Delta\tau$, $V(\tau)_i \le V_{oi}$	where, p_1 is position which informs about current volume of preproduct portions in the apparatus, $M(p_1) = V_{0i}$; p_2 is position which informs about current volume of the portion processed in the apparatus; p_3 is position which informs about space in the apparatus, $M(p_2) = V_{0i} - V(\tau)_i$; t_1 is transition modelling preproduct portion charge in the apparatus, t_2 is transition which models processing of the portion charged, t_3 is transition which models discharge of the portion processed

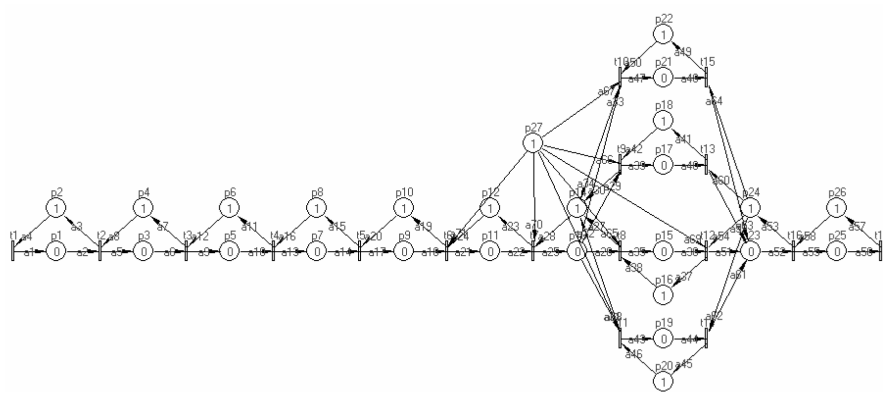


Fig. 2: Model of technological module as MPN

$$I(t_j) = \{p_i \quad P/I(p_i, t_j) = 1\}$$
$$O(t_j) = \{p_i \quad P/O(p_i, t_j) = 1\} \tag{1}$$

Enabling the transition changes the marking instantaneously (p) = (M (p_1), M (p_2), M (p_3),..., M (p_n)) for marking M/(p) by the following rule:

$$M/(p) = M(p) - I(t_j) + O(t_j) \tag{2}$$

Equation 2 means that the transition t_j subducts one marking from the position of each of its input and adds one marking to each of the outputs. The dynamics of MPN is determined by marking movement which simulates discrete flow balance of preproduct in the defined limits by the volume of wastewater treatment plants. The real state of individual apparatus (positions) for the biochemical and engineering production in analytical and graphical form may be presented in Table 1. PN modification considered enables to analyze the functioning of the system devices in emergency, the switching control at the network level as well as flow charts of discrete -continuous production for sustainable, stable system state. To control wastewater treatment process, a mathematical model of the technological scheme and its software implementation was developed. A mathematical model of the biological wastewater treatment system is designed in the form of MPN whose implementation will help to investigate system communications and the rules for unit functioning as a whole. Models of basic devices are also constructed, they implement biological wastewater treatment process (Yao *et al*., 2010). Model of the entire plant was synthesized from PN models of typical apparatus (Fig. 2).

Using the PN-Model, software of wastewater treatment process module which simulates the operation of treatment in virtual time was designed. Software package for wastewater treatment process control system was developed with means of SCADA TRACE MODE (Nasby and Phillips, 2011). The process control system allows supervisory control of the main elements of the management system, to stop wastewater treatment system and analyze its state as a whole and to predict the development of emergency situations (Huilinir *et al*., 2011).

CONCLUSION

When analyzing biochemical and engineering flow diagrams, one should consider the main limitation of the N-scheme formalism that consists in the fact that they do not account for the time characteristics of the simulated systems. This leads to the need for a modification of the PN that is focused on modeling and analysis of discrete-continuous chemical processes by prioritizing transitions, timing marks in positions and transitions. Constructing mathematical models of systems functioning of biochemical treatment of process effluents of paint manufacture in the form of modified Petri nets enables to study the system communications and the rules for the entire system functioning. The developed software of biological wastewater treatment systems enables to analyze the state of the treatment system as a whole and to predict the development of emergency situations (Azimov *et al*., 2015).

REFERENCES

Azimov, Y.I., I.I. Ismagilov and S.N. Savdur, 2015. Network modelling of functioning system of the process module of oil-contaminated wastewater treatment. Asian Soc. Sci., 11: 313-317.

Barzegar, B. and H. Motameni, 2011. Modeling and simulation firewall using colored petri net. World Appl. Sci. J., 15: 826-830.

Buswell, A.M. and H.F. Mueller, 1952. Mechanism of methane fermentation. Ind. Eng. Chem., 44: 550-552.

Fesina, E. and S. Savdur, 2014. Modeling of sewage bioremediation as a modified petri net. World Appl. Sci. J., 31: 1191-1197.

Haroonabadi, A., M. Teshnehlab and A. Movaghar, 2008. A novel method for behavior modeling in uncertain information systems. World Applied Sci. J., 3: 797-805.

Huilinir, C., E. Aspe and M. Roeckel, 2011. Modeling of the denitrification-anaerobic digestion process of salmon fishery wastewater in a biofilm tubular reactor. J. Environ. Manage., 92: 1591-1608.

Hunt, J.C.R., Y. Timoshkina, P.J. Baudains and S.R. Bishop, 2012. System dynamics applied to operations and policy decisions. Eur. Rev., 20: 324-342.

Motameni, H., A. Movaghar, B. Shiraz, B. Aminzadeh and H. Samadi, 2008. Analysis software with an object-oriented petri net model. World Applied Sci. J., 3: 565-576.

Nasby, G. and M. Phillips, 2011. SCADA standardization: Modernization of a municipal waterworks with SCADA standardization; Past, present and planning for the future. Tech., 58: 5-6.

Pitter, P., 1976. Determination of biological degradability of organic substances. Water Res., 10: 231-235.

Ruiz, M., G. Sin, X. Berjaga, J. Colprim and S. Puig *et al*., 2011. Multivariate principal component analysis and case-based reasoning for monitoring, fault detection and diagnosis in a WWTP. Water Sci. Technol., 64: 1661-1667.

Yao, A.W., Z. Ji and H.T. Liao, 2010. A petri nets-based process planning system for wastewater treatment. Asian J. Control, 12: 281-291.

Zhou, M. and Z. Li, 2010. Special issue on petri nets for system control and automation. Asian J. Control, 12: 237-239.