Modeling of wastewater treatment system of car parks from petroleum products

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Abstract. The paper discusses the technological complex of wastewater treatment of car parks from petroleum products. Based on the review of the main modeling methods of discrete-continuous chemical and engineering processes, it substantiates expediency of using the theory of Petri nets (PN) for modeling the process of wastewater treatment of car parks from petroleum products. It is proposed to use a modification of Petri nets which is focused on modeling and analysis of discrete-continuous chemical and engineering 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.

1. 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 there is task complexity of modeling and analysis of such systems, it is necessary to apply modern methods of mathematical and computer modeling.

2. 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.

3. Theory
Parking usually has open areas and well-developed road network with rainwater drainage. Rainwaters are usually polluted by suspended substances, petroleum products and other substances.

Parking wastewater is a danger for the environment and should be cleaned in accordance with the established environmental standards before discharge.

The cleaning systems should be compact, easy to use and effective. In addition, such systems should have low delivery, installation and maintenance cost.

Modern process systems of wastewater treatment have a complex multi-layered structure; therefore, they can be considered as complex cybernetic systems [1]. 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 [2].

In accordance with the principles of system analysis, an industrial wastewater treatment plant is a chemical and engineering system, which includes a set of interrelated material, thermal and
information flow units, each having a hierarchical structure [3]. 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 [4]. 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 [5, 6]. 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 [7, 8], provided there is its stationary nature and the invarableness of physical and chemical parameters. In the second approach, the object is represented as a dynamic system with discrete variable. 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 [9]. Comparative analysis as the primary unit of mathematical modeling helps to select the PN theory [9]. PN enables one to simulate discrete parallel asynchronous processes [9], to get a graphical representation of the network, to describe the system at different abstraction levels, to present the system hierarchy [10], to analyze models using modern software packages.

4. Results
Applying the methods of system analysis enables one to develop a control system of plants of wastewater treatment of car parks from petroleum products (Fig.1), which provides for the construction of a mathematical model based on the PN.

Figure 1. Simplified technological system of cleaning car parks from wastewater

Figure 1 shows: G – Grille; S – Sand separator; AT – Accumulating tank; H – Hydro cyclone; GF – Granular filter; F – Unwoven cloth filter; C1 – Capacity to collect sand; C2,4 – Container for sediment transporting; C3 – Container for oil products collection; C5,6,7 – Container for purified water collection.

To describe the system, let us propose using N-schemes, based on the mathematical apparatus of Petri nets, whose advantage is possible representation of the network model both in the analytical
form, automating the process of analysis, and in the graphical form, providing visualization of the model developed.

When analyzing chemical 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. Having these conditions, the authors have proposed the modified Petri net. MPN is Petri net in the form of:

$$ C = \langle P, T, I, O, M, L, \tau_1, \tau_2 \rangle,$$

where $T = \{t_j\}$ - finite non-empty set of symbols called transitions, which are measured depending on the number of conventional product portions with a continuous feeding to the apparatus in the process flow.

$P = \{p_i\}$- finite non-empty set of symbols called positions. In this case, it is a set of process flow devices;

$I: P \times T \rightarrow \{0, 1\}$ - input function, which for each $t_j$ transition gives the set its position $p_i \in I(t_j)$.

$O: P \times T \rightarrow \{0, 1\}$ - the output function, which reflects a transition to the set of output positions $p_i \in O(t_j)$.

$M: P \rightarrow \{1, 2, 3, \ldots\}$ – 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.

$\tau_1: T \rightarrow N$ и $\tau_2 : P \rightarrow N$ 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:

$$I(t_j) = \left\{ p_i \in P_{\text{in} \leftarrow t_j} = 1 \right\} \text{ and } O(t_j) = \left\{ p_i \in P_{\text{out} \rightarrow t_j} = 1 \right\} \quad (1)$$

Enabling the transition changes the marking instantaneously $M(p) = (M(p_1), M(p_2), M(p_3)\ldots M(p_n))$ for marking $M'(p)$ by the following rule:

$$M'(p) = M(p) - I(t_j) + O(t_j) \quad (2)$$

Equation (2) means that 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 pre-product in the defined limits by the volume of wastewater treatment plants.

The PN modification considered enables one 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 the wastewater treatment process, a mathematical model of the technological scheme and its software implementation was developed. A mathematical model of the 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 the wastewater treatment process [11]. The model of the entire plant was synthesized from PN models of a typical apparatus (Fig. 2).

Using the PN-model, software of the process module of wastewater treatment that 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 [12]. The process control system allows supervisory control of the main elements of the management system, to stop the wastewater treatment system and analyze its state as a whole and to predict the development of emergency situations [4].
5. Conclusion
When analyzing chemical 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 and engineering processes by prioritizing transitions, timing marks in positions and transitions. Constructing mathematical models of systems functioning of wastewater cleaning of car parks from petroleum products in the form of modified Petri nets enables one to study the system communications and the rules for the entire system functioning. The developed software of wastewater treatment systems enables one to analyze the state of the treatment system as a whole and to predict the development of emergency situations [13].

References
[1] Fesina E, Savdur S Modeling of Sewage Bioremediation as a Modified Petri Net 2014 World Applied Sciences Journal 31 (6) 1191-1197
[2] Hunt J C R., Timoshkina Y, Baudains P J, Bishop S R. System Dynamics Applied to Operations and Policy Decisions 2012 European Review 20(3) 324–342
[3] Motameni H., Movaghar A., Shirazi B., Aminzadeh M., Samadi H Analysis Software with an Object-Oriented Petri Net Model 2008 World Applied Sciences Journal 3 (4), 565-576
[4] Huilinir C, Aspe E, Roeckel M Modeling of the denitrification/anaerobic digestion process of salmon fishery wastewater in a biofilm tubular reactor 2011 Journal of Environmental Management 92 1591-1608
[5] Haroonabadi A, Teshnehab M., Movaghar A A Novel Method for Behavior Modeling in Uncertain Information Systems 2008 World Applied Sciences Journal 3 (5) 797-805
[6] Ruiz M, Sin G, Berjaga X, Colprim J, Puig S, Colomer J Multivariate Principal Component Analysis and Case-Based Reasoning for monitoring, fault detection and diagnosis in a WWTP 2011 Water Science, Technology 64 (8) 1661–1667
[7] Peter P, Determination of Biological Degradability of Organic Substrates 1976 Water Research 10 231-235
[8] Buswell A M, Mueller M F Mechanisms of Methane Fermentation 1952 Industrial and Engineering Chemistry 44 550-552
[9] Guest Editors, MengChu Zhou, Li ZhiWu Special issue on «Petri nets for system control and automation» 2010 Asian Journal of Control 12 (3) 237-239
[10] Barzegar B, Motameni H Modeling and Simulation Firewall Using Colored Petri Net 2011
World Applied Sciences Journal 15 (6) 826-830
[11] Albert W, Yao L, Zhiming Ji, Liao H T A Petri nets-based process planning system for wastewater treatment 2010 Asian Journal of Control 12 (3) 281 – 291
[12] Nasby G., Phillips M SCADA standardization: Modernization of a municipal waterworks with SCADA standardization: Past, present, and planning for the future 2011 InTech 58 (5-6) 1
[13] Azimov Yu, Ismagilov I, Savdur S Network Modelling of Functioning System of the Process Module of Oil-Contaminated Wastewater Treatment 2015 Asian Social Science 11(11) 313 – 318