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WASTE AND WASTEWATER TREATMENT BOTTLENECK MANAGEMENT

A. Dychko, I. Opolinskyi, L. Yevtieieva
National Technical University of Ukraine "Kyiv Polytechnic Institute"
vul. Borschagivska, 115/3, Kyiv, 03056, Ukraine. E-mail: opolinskyi@gmail.com

Purpose. To create methodology of waste and wastewater treatment management with bottleneck considering. *Methodology.* Problem of waste management includes problems of its observation and identification, insuring reliability of monitoring data and their assessment. Intellectualization of management systems should consider the decision making theory and dynamic aspects of the process, automated conscious expert systems etc. *Results.* Effective management of bottlenecks of waste treatment should be based on developed methodic of decision making about implementation of quality increase. Use of comparing analysis of data of "nearest neighbors" insure detailing of system characteristics and give possibility to determine real reasons of parameters change and their mutual influence. Use of fuzzy set theory with reliable limits determination allows to insure optimal management. *Originality.* For the first time, effective management of waste and wastewater treatment enterprise was associated with problems of decision making on implementation of technologies, which improve quality. Methodology of decision making in waste treatment can be developed on base of Bayesian approach, logic programming, decision trees, the nearest neighbor methods, and use of fuzzy logic. *Practical value.* Developed algorithm of bottlenecks management includes stages for its effectiveness. *References 9, no tables, figure 1.*
Key words: waste, wastewater treatment, bottleneck, management, decision making.

МЕНЕДЖМЕНТ ПРОБЛЕМНИХ ПИТАНЬ ПЕРЕРОБКИ ВІДХОДІВ ТА ОЧИЩЕННЯ СТІЧНИХ ВОД

А. О. Дичко, І. О. Ополінський, Л. І. Євтєєва
Національний технічний університет України «Київський політехнічний інститут»
вул. Борщагівська, 115/3, корпус 22, м. Київ, 03056, Україна. E-mail: opolinskyi@gmail.com

Проблема поводження з відходами та очищення стічних вод включає в себе питання їх дослідження та ідентифікації, що забезпечує надійність даних моніторингу та його оцінки. Інтелектуалізація систем управління має враховувати питання теорії прийняття рішень і динамічні аспекти процесу, автоматизовані експертні системи тощо. Ефективне управління поводженням з відходами забезпечується розробленою методикою прийняття рішень. Використання порівняльного аналізу даних "найближчих сусідів" надає деталізацію характеристик системи і можливість визначити реальні причини зміни параметрів і їх взаємний вплив. Використання теорії нечітких множин з визначенням надійних меж забезпечує оптимальне управління. Методологія прийняття рішень при переробці відходів та очищенні стічних вод базується на основі підходу Байєса, логічного програмування, дерева рішень, методу «найближчих сусідів», а також використання нечіткої логіки. Розроблений алгоритм управління вузькими місцями включає в себе етапи, що підвищують його ефективність.
Ключові слова: відходи, стічні води, переробка, вузькі місця, управління.

PROBLEM STATEMENT. Waste and wastewater treatment systems even before the independence of Ukraine entered a period of continuous crisis, which is caused by both physical depreciation of technical equipment, underdeveloped technologies, social and economic problems. The main causes of deterioration of the quality of biochemical wastewater treatment can be identified as a high concentration of pollutants in wastewater, sharp fluctuations of quantitative indicators and quality of effluents, suboptimal content of nutrients in the culture fluid and so on. In addition, the old treatment equipment is unable to cope with the continuing increase of toxic pollutants in wastes and certain chemicals, including phosphates, in wastewaters [1-3].

Efforts to reform the industry do not give the expected effects without the system approach that would take into account integral technical, economic and social issues and environmental issues, densely interconnected and influence each other.

EXPERIMENTAL PART AND RESULTS OBTAINED. Waste treatment system is the complex system, which is influenced by both internal (technical, social, economic and environmental) and external (social and political conflicts, global environmental problems, external debt, structural limitations) factors. Therefore, it is important to consider in the context of complex systems that can be developed.

Using results of observations and analogies suggests that the structures and functioning of waste treatment system demonstrate broadly self-similarity: organic waste biotransformation into biogas or cleaning water from pollution both in vivo and in various waste treatment plants takes place at the same principles and differs only in purification productivity and treatment quality that systems are more or less equally included in a wide range of spatial, temporal and quantitative scales (scales), indicating the presence of a certain symmetry scales. In other words, these purification processes like filtration, gravitational sedimentation, adsorption,

chemical and biological treatment, sublimation, dissolution, disinfection (e.g. UV radiation) etc. typical as for small natural whether artificial treatment facilities and modern complex system as a whole. In this case, the research of similar systems can use fractal analysis methods and elements of chaos theory.

The problem of waste management includes problems of its observation and identification, insuring reliability of monitoring data and their assessment. Intellectualization of management systems should consider the decision making theory and dynamic aspects of the process, automated conscious expert systems etc. The Theory of Constraints, or TOC, is a method to guide organizational change based on reducing the impact of bottlenecks [4, 5].

Today, the methods of analysis of complex systems are widely used, mainly on technical, environmental and economic systems [6-8]. Moreover it comes to systems that are described or based on deterministic functions, or using methods of mathematical statistics.

Analysis of complex system must adhere to basic principles:

− Simplification (to reasonable limits) of processes and structures for their adequate understanding;

− Their consideration at dynamics and for perspective;

− Taking into account the possibility of ambiguity and unpredictability;

− Understanding of system as a hierarchical structure that is able to adaptation and development.

− For the formation of adaptive cycle of development (model of system) must be considered the three main characteristics [9]:

− Inherent potential of the system, which includes the necessary changes in case of need (*resource*);

− Internal control (*connectedness*) of the system, in the degree connectedness between internal processes and controlled variables (a measure that reflects the degree of flexibility or rigidity of control sensitivity or insensitivity to disturbances);

− Adaptability, *resilience* of the system (a measure of vulnerability relatively to unexpected or unpredictable stress).

Effective management of enterprise is associated with problems of decision making on the implementation of technologies, which improve the quality. Methodology of decision making on the abovementioned problems can be developed on base of Bayesian approach, logic programming, decision trees, the nearest neighbor methods, and the use of fuzzy logic.

Methods of fuzzy theory and theory of abilities use instead of determinate functions, which connect between themselves input data, variables, outside factors and parameters with outputs, functions of belonging etc. Hierarchy principle of the main parameters allows to take off so named "curse of dimensionality", connected with difficulty of development of system at in- and output with great amount of state parameters. It's connected with people's ability to remember operatively simultaneously up to 7 ± 2 characteristics. That's why it's desirable to develop

hierarchy classification of parameters of state with conclusion tree build, which will determine system of input one-by-one parameters of less size.

Hierarchy principle allows to take into account a lot of parameters of state of system and new states that appear later. At the same time the rules become easier and their amount is decrease by this principle.

According to the principle of three variants estimation of parameters of state the observed parameter of the system is estimated by one of the variants: quantities data, linguistic characteristics or by thermometer principle. Parameter is estimated by possibility of quantities estimation of parameter of state and presence of instrumental facilities of measuring.

To project the intellectual part of management system it's necessary to know: range of possible causes of process effectiveness decrease; tree of fuzzy conclusion; base of fuzzy rules *IF {...},THEN {...}*; educating choosing.

Reasons of decrease of effectiveness of system functioning may be classified by certain way. Such classification should be maximally deep for the earliest stages of determination of mistakes of equipment functioning while operating visual information or obtained not always exact express-determinations. Necessary reliability of analysis of process effectiveness reduce may be obtained by detailed laboratory measuring and calculations. Determination of class of reasons at the earliest stages of diagnostics allows to deal with certain problem more detail decreasing time and forces for determination of reason of treatment quality decrease.

The algorithm of bottlenecks management includes the next (Fig. 1):

Step 1. *Clear definition of the purpose* of innovation application: what important (unique) features will characterize it, what is the cost of a system, who will exploit it and who will benefit from the operation of the system, what is the value of these expected results? This requires the selection of the parameter for evaluation of the effectiveness of implementation. It may be capacity, performance, special product characteristics (sustainability etc.) or more universal indicator - "effectiveness/cost".

Step 2. *Identification of bottlenecks* of system that is proposed, as such, for example, indicators as productivity, are determined by their bottlenecks. Chain may always have a weak link, so all attention should be paid to "strengthening" of the link. To identify bottleneck following situations may be signs of it:

− Maximum load level, although this is not always a sign of a bottleneck on which the problem could be found (sometimes even system are optimizing on the basis of the maximum load of all resources). Availability of nodes which receive flows of information, materials, finished goods etc.

− The presence of downtimes of equipment, subsystems, vehicles, etc. in a locked technological process.

If there are obvious signs of one or more bottlenecks, it indicates that the system designers should look at the system through the eyes of those who will

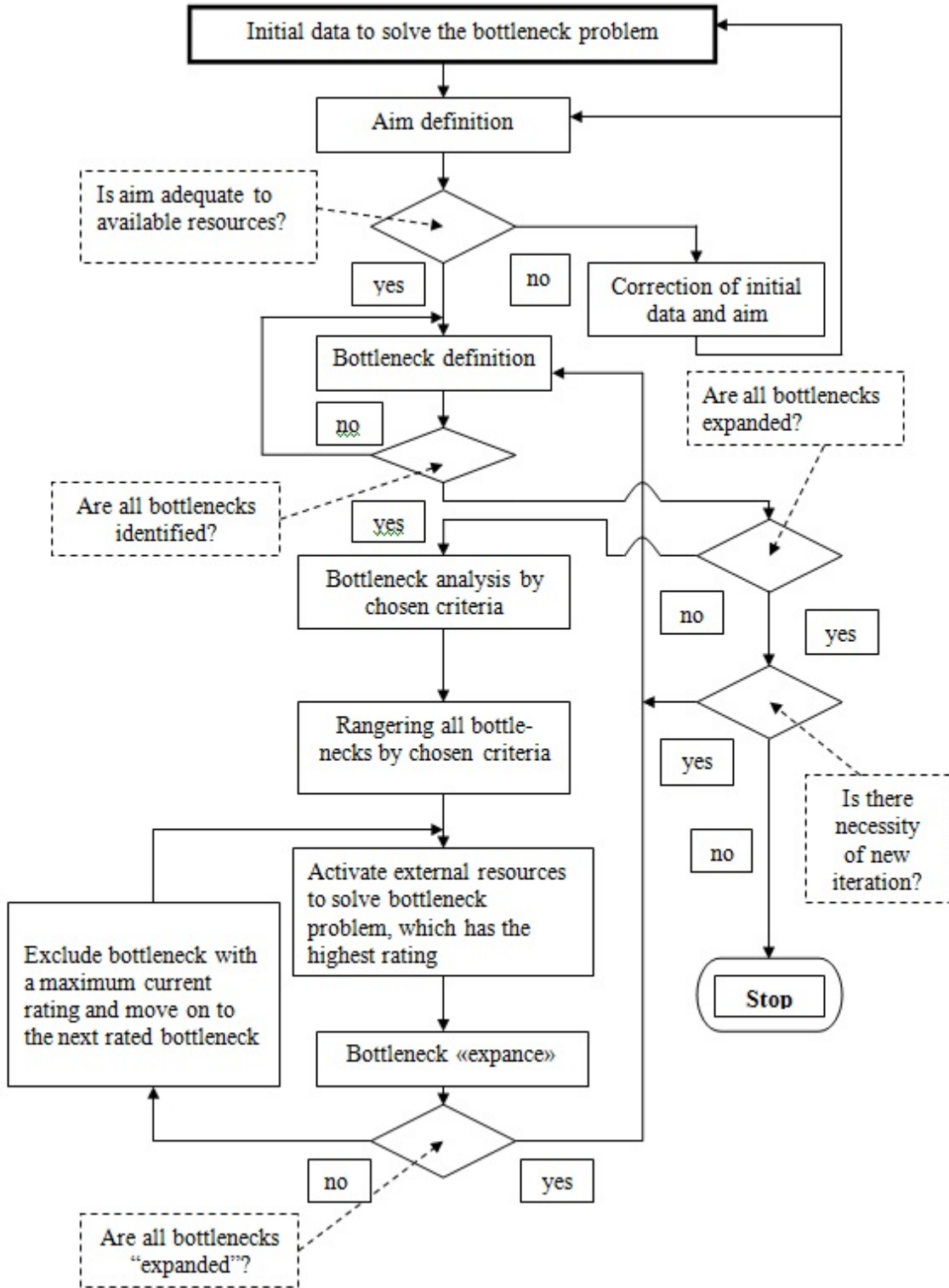use it and should make some adjustments to documentation.

Figure 1 – Block diagram of algorithm of bottleneck management

Step 3. *Analysis of bottleneck*: if productivity or capacity of the system is determined by the capacity of bottleneck, it's necessary; above all, to increase its performance; if it is a downtime of the bottleneck, it's necessary to analyze their causes and to remove or minimize them. The next should be realized for that:
– Remove any nonessential additional work (operations) which may be translated into other parts of

the system.
– Eliminate or limit interruptions. Eliminate obstacles.
– Insure the bottleneck work in a stable mode. Ensure the use of quality materials and capital goods.
– Ensure prioritization of tasks for the bottleneck that it will always service the highest priority tasks.
– Provide with sufficient information the

developers about the necessary improvement of the system, and the head of the development team must accept, classify and prioritize requests and messages, and fixing of errors needs in case of the next mistakes be activated to provide a good balance between the activities of developers working on the next iteration (improvement of the system on the basis of comments received earlier), and a sense of duty system problems. It should be understood that it is impossible to estrange the developers from such useful information as customer requirements, system performance changes (replacement) of equipment or process units, user reviews.

It is necessary to start from the analysis of bottlenecks because this step of improvement of the system is relatively easy: it does not require much funds or investments and requires only one resource.

Step 4. *Submission* of every other solution to the problem of bottleneck. All the resources which are not, by definition, the bottleneck resources, should be considered as a reserve, that in case of necessity can be directed to support bottleneck. Submission can be done as follows:

– Movement of less meaningful work of bottleneck on other parts of system.

– All parts of the system should work in accordance with the bottleneck mode: no faster or slower to avoid overloading the bottleneck in the future.

– Buffer of works at entrance of bottleneck must always be more or less full.

– At the exit of bottleneck there should be a buffer to ensure stable operation of the system in case of variations at the output of bottleneck.

– All parts of the system must apply for bottleneck entry quality only (certified) signals, goods, raw materials and so on.

– Special development team should be completely subordinated to solve problems in the bottleneck that arise: in case of any questions, demands, problems connected with the performance or latency, an urgent need to focus on these issues.

– A customer should participate in testing a system to promptly inform developers about their suggestions and comments to improve the system.

– A customer's on-site supervisor and a special development team should prepare a new iteration of improvements with the aim to hold always a special team the developers in the "form".

Thus subordination - is the easy process: it does not require much funds or investments and requires little resources, especially those that directly interact with bottleneck. But there is also one aspect of submission: while the bottleneck resources should be fully used, other resources should have reserve of time to support bottleneck in the case of variations at its output.

Step 5. *"Expansion" of bottleneck*. This step most managers intuitively make first: an increasing number of workers, machinery, equipment, and training and control procedures. But this step should be done when most of the "free" improving procedures introduced in the previous steps, implemented. It was then they apply to the following measures:

– Increase number and quality of performers working in parallel;

– Implementation of different methods of training and more careful control of the personnel and equipment;

– Use of improved means and methods of production, more high-speed machinery, more efficient methods and tools for information processing, etc.;

– Implementation of more efficient technologies.

"Expansion" of bottleneck in contrast to the first steps requires significant investment. In addition, the introduction of improvements at this stage is dangerous, because most of these "improvements" require some time to get results and, under certain conditions, on the initial stage of "improvement" may even lead to negative results before it gives the desired "improvement". For example, increasing the number of performer's speed of work may be reduced while new performers will not take the experience and will be not in the rhythm of coordinated team.

Step 6. *Return to Step 1*, in the next iteration of all of the above procedures. When we take a step to improve and get a positive result, we start all things from the beginning. The team gathered to solve the bottleneck problem, better and faster repeats the procedure of bottleneck "expansion" and provides more information for system developers. This happens (should happen) while implementing new systems. But in case of optimization of existing systems or upgrading above steps are valid:

– The main purpose of optimization whether upgrading and risks associated with their implementation are determined;

– Bottlenecks of the current system are identified and analyzed, each of which is characterized by a general contribution to the deterioration of the system, means for its removal, the time needed to implement the removal, effects on other parts of the system, the impact on the future development of the system and so on and priority;

– All decisions that are not directly related to the bottleneck are subject to solve the bottleneck problem.

CONCLUSIONS. Effective management of bottlenecks of waste and wastewater treatment should be based on developed methodic of decision making about implementation of quality increase. Use of comparing analysis of data of "nearest neighbors" insure not only detailing of system characteristics, but give a possibility to determine real reasons of parameters change and their mutual influence. Use of fuzzy set theory with reliable limits determination, in which there are appropriate estimations of certain parameters, allows to insure optimal management of bottlenecks of waste treatment.

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МЕНЕДЖМЕНТ ПРОБЛЕМНЫХ ВОПРОСОВ ПЕРЕРАБОТКИ ОТХОДОВ И ОЧИСТКИ СТОЧНЫХ ВОД

А. О. Дичко, И. О. Ополинский, Л. И. Евтеева
Национальный технический университет Украины «Киевский политехнический институт»
ул. Борщаговская, 115/3, корпус 22, г. Киев, 03056, Украина. E-mail: opolinskyi@gmail.com

Проблема обращения с отходами и очистки сточных вод включает в себя вопросы их исследования и идентификации, обеспечивая надежность данных мониторинга и его оценки. Интеллектуализация систем управления должна учитывать вопросы теории принятия решений и динамические аспекты процесса, автоматизированные экспертные системы и тому подобное. Эффективное управление обращением с отходами обеспечивается разработанной методикой принятия решений. Использование сравнительного анализа данных "ближайших соседей" предоставляет детализацию характеристик системы и определяет реальные причины изменения параметров и их взаимное влияние. Использование теории нечетких множеств с определением надежных границ обеспечивает оптимальное управление. Методология принятия решений при переработке отходов и очистке сточных вод базируется на основе подхода Байеса, логического программирования, дерева решений, метода «ближайших соседей», а также использование нечеткой логики. Разработанный алгоритм управления узкими местами включает в себя этапы, повышающие его эффективность.

Ключевые слова: отходы, сточные воды, переработка, узкие места, управление.