

# Water-saving processes control of an airport

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**Abstract.** This article presents a systematic approach to solving a problem with rational use of an airport's water resources. Life cycle programming of the technological systems of wastewater purification allowed to consider comprehensively the problem of economical water consumption. The life cycle programming was adopted as the methodological basis for constructing a logical scheme of tasks of an airport's water-saving processes. On the basis of the proposed logical tasks diagram it became possible to develop an algorithm and software for automatized control over airport's water-saving processes. The purpose of the work is to implement a systematic approach for control over water-saving production aviation processes of the airport and representation of the developed algorithm for control. It may be concluded that the implementation of the given algorithm on the basis of computer technology will increase the efficiency of wastewater purification and significantly reduce the fresh water consumption.

## 1 Introduction

Contamination with harmful substances discharges into the environment, underground water and soil in the area of the airport location is one of the factors of the unfavorable human activities impact on the environment [1]. The main source of pollution of water basins is the wastewater discharge making significant contribution to the environmental pollution. Airports are intense sources of wastewater consisting of industrial, household and surface run off. Waste dumped in water basins, poisons not only surface but also underground water. Today, all countries, without exception have a task to preserve water resources. The extremely urgent problem of providing people with water suitable for consumption is becoming relevant in many regions [2].

Standards for emissions of pollutants into the environment and demands to reduce the consumption of fresh water from water sources are currently getting stricter in order to protect the environment and natural resources. There is also a high price on water. All these factors will definitely contribute to more economical water consumption.

Quantity and quality of wastewater changes during the day, week, month, testifying about unsteadiness of the aviation and airport operations. For a number of air transport operations, the volley discharges of highly concentrated wastewater are typical. Therefore,

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solving the problem of economical water consumption is possible only in the conditions of the automated system of control over water-saving processes functioning, safe for consumption after perturbation of input parameters of determining the control effects in an optimal way.

The necessity of developing and implementing automated systems of control over water-saving processes is conditioned by the following factors:

- non-stationary processes of wastewater purification;
- the complexity of the cleaning processes themselves (physical, chemical, biological purification, etc.);
- high requirements for cleaning parameters, including the requirements offered by international standards;
- the implementation of cleaning systems involves the need for large-scale use of a number of different blocks (sometimes over 100).

Monitoring and control a large number of parameters goes beyond the scope even of an experienced operator. Therefore, work that increases efficiency of the purification facilities functioning, including the development of automated systems by water conservation, is topical.

According to the above-mentioned information, there appears to be a need to implement a systematic approach to solving the problem of water resources rational use at all levels of airport's management. As for the functioning of the automated control system, the presence of the appropriate algorithm and software is required.

Study of control of wastewater purification processes problem [3-8] makes it possible to conclude that, due to the current strengthening of the norms for the emission of pollutions into the environment, local specialized enterprises are solving local problems of control automation at the technological level, not allowing to consider tasks for water resources reuse in a complex way at all the levels of the airport management. In the absence of water, this leads to harm to the environment and water resources irrational use.

## **2 The life cycle of the technological system of wastewater purification as a logical and informational basis for the construction of the integrated automated control system**

Life cycles programming of new technology objects (including integrated automated control systems) is the logical and informational basis for the formation of processes of system formation, target reaching and development, providing tackling the complex automation tasks on a single information basis - a databank [9].

The life cycle programming of the technological purification system means the process of planning the achievement of the specified targets of the technological purification system by:

- optimal allocation of resources at all stages of the life cycle;
- achieving maximum technical and economic efficiency of systems and processes for the design, construction and operation of a technological purification system .

In the target aspect of life cycle programming of the technological purification system is a process of optimal planning and management of the development and use of generations of technological purification systems based on system criteria for the efficiency of the design, construction and operation processes.

The life cycle of the technological purification system is also a structural and functional basis for targeted planning, creation and improvement of the purification system. The program-purpose fulness of the life cycle allows to provide on a single information basis the uniform requirements to all structural and functional elements, regardless of the fact

that enterprises, organizations and institutions involved in their implementation may belong to different departments and ministries.

The full life cycle [10, 11, 12] includes the following stages:

scientific research and designing → manufacturing and realization → exploitation.

The use of water after its purification for the technological purposes of the aviation and airport operations is primarily connected with economic purposes. The fact is that even after significant dilution, the cost of wastewater purification is very high. If you take the cost of cleaning by 90% for 1 unit, then the cleaning by 99% is 10 times more expensive, and cleaning by 99,9% (which is most often required) will be already 100 times more expensive, therefore, it will be 100 units. As a result of the purification of wastewater from the distinctive pollution for this type of drains in the case of re-use it is much cheaper than their complete purification.

For the meaningful formulation of the target-reaching in the process of functioning of the airport's integrated automated control system by production aviation processes, the life cycle through decomposition is represented and used as a "small life cycle" the water resources to be included in the following structural and functional stages:

exploitation I → research of wastewater content → preparation of solutions at the production level → implementation of solutions at the technological level → exploitation II.

In the life cycle, the basic information and organizational principles of the implementation of targeted planning on the basis of the creation of an Integrated automated control system are standardized. The airport's integrated automated control system is a set of control subsystems, interacting on the basis of technical, informational and logical means in accordance with control levels: organizational and economic, productional, technological.

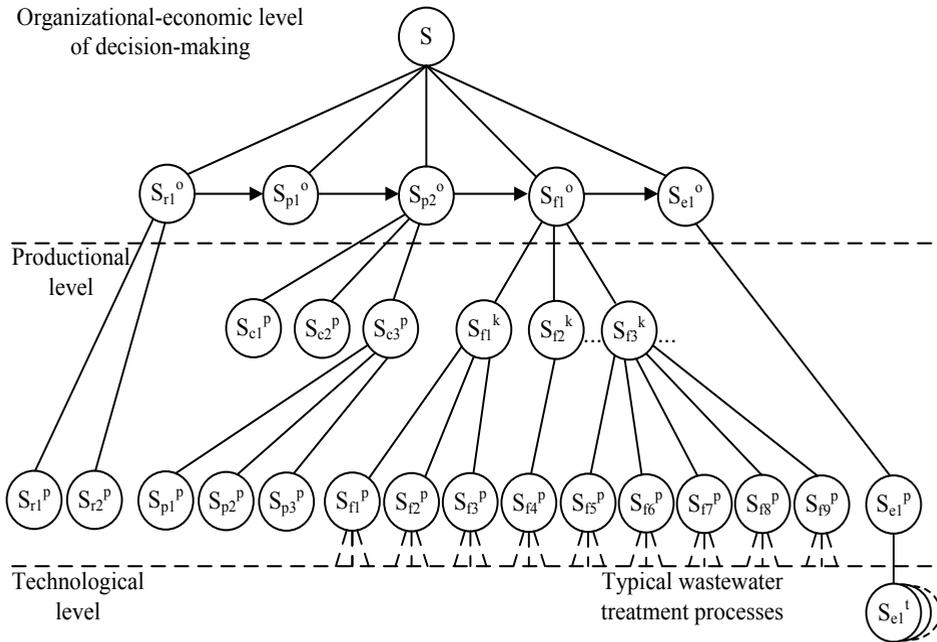
The functional subsystems of airport's integrated automated control system, formed in accordance with the decision-making levels, consist of the following:

- subsystem of calendar planning and management of production aviation processes (organizational and economic level);
- subsystem of automated control of the airport's water-saving processes (productional level);
- subsystem of automated control of typical processes wastewater purification (technological level).

The basis of the implementation of the above mentioned subsystems is the formation of the tasks' structure ensuring their operation in a given mode. There are currently no set rules to determine the way of combining methods into a single strategy for optimal distribution of water resources for production aviation and airport processes. In solving this problem both formal and informal methods are effectively combined. Let us base the logical scheme of tasks, as models of obtaining solutions, on a sequentially parallel deductive scheme in certain axiomatically formalized elements taking into account the features and specifics of the technological system of wastewater purification. We consider the system procedure  $T$  as an oriented diagram (fig. 1), containing cells of the logical scheme for solving tasks in its vertices. The diagram arches reflect the dynamics of the solution of the entire  $S \{S_i\}$  problem. The implementation of the  $T$  procedure is represented as the process of converting the input information of  $A_i$  and  $C_i$  to solve the  $S_i$  task. Therefore, in the formalized interpretation, the logical scheme is given by the five units ( $S, A, C, T, R$ ), where  $S$  is a non-empty set of tasks,  $A$  is a finite set of input data,  $C$  is a finite set of constraints,  $T$  is a system decision procedure,  $R$  is a non-negative set representing a solution.

The cell of the logical tasks scheme  $S$  is denoted as follows:  $\langle A, C, M, T, R, K \rangle$ . The solution of decomposed  $S_{np}$  task may be formalized in the form of an ordered six units  $\langle A,$

C, M, T, R, K>, where A is the input data, C is a constraint, M is a mathematical model, T is a solution method, R is a solution, K is a criterion for evaluating the solution. The informative side of constructing a logical scheme is reduced to the formation of a set of tasks  $\{S_{np}\}$  and the ordering of their solutions across the range of the index set  $i$ , which ensures the full possibility of solving the outgoing problem S. Let us list each of the tasks shown in Figure 1.



**Fig. 1.** Logical scheme of tasks in IACS of airport's water-saving processes.

$S_{r1}^o$  - the task of obtaining the characteristics of wastewater and entering them into the database.

$S_{r1}^p$  - the task of the analysis of wastewater content.

$S_{r2}^p$  - the task of developing water requirements after cleaning.

$S_{p1}^o$  - the task of synthesis of the technological scheme of wastewater purification.

$S_{p2}^o$  - the task of evaluating the system properties of a technological purification system, which is decomposed into the following local tasks.

$S_{c1}^o$  - the task of estimating the damage from harmful emissions for society.

$S_{c2}^p$  - the system controllability estimation task of technological purification system.

$S_{c3}^p$  - the task of evaluating the sensitivity of a technological purification system is decomposed into the following local tasks.

$S_{p1}^p$  - the task of estimating apparatus contribution to the changes in the input characteristics of the technological scheme.

$S_{p2}^p$  - the task of estimating the computational modules' parametric sensitivity.

$S_{p3}^p$  - the task of estimating the variation of the output characteristics of processes at variation of parameters.

$S_{f1}^o$  - the task of calculating the material balance of the technological purification scheme, is carried out with the help of docking computing modules for calculating the material balance of the purification units.

$S_{f1}^k$  - the task of calculating the material balance of the adsorption purification unit.

$S_{f1}^p$  - the task of optimal choice of the equipment type for the adsorption purification unit.

$S_{D2}^p$  – the task of calculating the multistage adsorber's material balance.

$S_{F3}^p$  – the task of calculating the absorber's material balance for the mode of the fluidized bed adsorbent.

$S_{D2}^k$  – the task of calculating the material balance of the mechanical purification unit.

$S_{F4}^p$  – task of calculation the technological and structural parameters of mechanical purification apparatus.

$S_{B3}^k$  – the task of calculation the material balance of physical and chemical purification unit.

$S_{F5}^p$  – the task of calculating the required dose of a reagent for the wastewater purification.

$S_{F6}^p$  – the task of calculating the material balance, technological and structural parameters of the sedimentation tank.

$S_{F7}^p$  – task of calculation of material balance, technological and structural filters' parameters.

$S_{F8}^p$  – the task of calculating the material balance of the mixing process.

$S_{F9}^p$  – the task of identifying the kinetic parameters of the reagent wastewater purification.

$S_{F1}^k$  – ... the task of calculating the material balance of the typical wastewater treatment process .

$S_{e1}^o$  – the task of determining the water resource needs of an enterprise taking into account the reuse of water;

$S_{e1}^p$  – the task of determining the optimal control parameters for a control system of typical wastewater treatment processes;

$S_{e1}^t$  – the task of determining the matrix of control actions for a typical wastewater treatment process after disturbing the parameters at the input of the system.

The wastewater purification quality depends on the data reliability about the operation mode of aviation specialized enterprises, some buildings at airport and the composition of wastewater. Therefore, in order to effectively control water-saving processes, it is necessary to have relevant information that provides control of the main technological parameters provided by the regulatory documents. The operation of the wastewater treatment system depends to a large extent, on the changes, arising on an aviation specialized enterprise and some buildings at airport. Therefore, the solution of the problems of wastewater purification control should be carried out within the framework of the Integrated automated control system (IACS). In this regard, when developing IACS it is possible to allocate, in addition to the system-wide principles of the creation of automated control systems, proposed by academician Victor Glushkov (principles of systemicity, compatibility, standardization, information unity, modularity, new tasks, first manager), the following principles which aim at the developing a subsystem for control of airport's water- saving processes.

- The principle of dynamic matching between the innovations introduced by the specialized airline and the state of the subsystem database.

For the implementation of this principle, reliable information on the composition of the wastewater is required. In order to receive this information in time, it is necessary to organize an automated workplace "Laboratory". This is due to the fact that many indicators of water quality are still determined analytically (except for pH, turbidity, electrical conductivity and some others are having appropriate sensors).

- The principle of the aggregation automated system.

The second principle ensures the creation of a subsystem by aggregation into a single control complex of individual automated subsystems of airport that operate on a single methodological, information, and programmatic basis, both horizontally in the stages of the

life cycle (research, design, operation), and in the vertical control (organizational and economic level, productional, technological levels).

- The principle of complexity.

The third principle means that the optimal tasks of the subsystem of water-saving processes' control are determined on the basis of innovations made by an aviation specialized enterprises, airport's some buildings on wastewater purification costs and environmental damage.

The basis for the implementation of the informational unity principle is the information flows of the operational control subsystem, based on a comprehensive record of information, on the progress of processes aviation production, and provide timely correction of control influences.

Operative control of water-saving processes is carried out by the operator, who makes a connection with the purification installations which is based on the task received from the Automated control system of the aviation specialized enterprises, water quality indicators, documentary information and the usage of the automated calculations results on the control computer.

After the development of the logical structure of the tasks, the analysis of the sets of input data, constraints, methods for solving the tasks of operational control of the water saving processes is carried out, which allows us to proceed to the types of Integrated automated control system development support ( algorithmic and software).

### 3 Optimization tasks solved by the automated control subsystem of the airport's water-saving processes

The proposed approach for rational water consumption and water purification at its first stage includes the assessment of the needs of specialized aviation enterprise divisions and airport operations in water resources, carried out at the organizational and economic management level.

#### 3.1 Organizational and economic decision-making level

Target function looks like:

$$W_1 = \sum_{i=1}^n \sum_{j=1}^m C_{ji} Q_{ji} (1 + k_{ji}) \rightarrow \min \quad (1)$$

Restrictions are described by the following ration:

$$\sum_{i=1}^n \sum_{j=1}^m Q_{ji} \leq \bar{C}, \quad \sum_{i=1}^n \sum_{j=1}^m Q_{ji} \leq \bar{Q}_{ji}, \quad \sum_{i=1}^n \sum_{j=1}^m \bar{Q}_{ji} \leq L_{ji}, \quad Q_{ji} \geq 0, \quad C_{ji} \geq 0, \quad k_{ji} \geq 0,$$

where:  $Q_{ji}$  is water usage, needed for normal functioning of  $j$ -aviation or airport process at the  $i$ -time;  $C_{ji}$  is the price of water expenditure during a  $j$ -aviation or airport process at the  $i$ -time;  $k_{ji}$  is the level of reuse of water by the  $j$ -aviation or airport process at the  $i$ -time;  $\bar{C}$  is expenses norms stipulated by the financial plan;  $\bar{Q}_{ji}$  is limit of water consumption during the  $j$ -aviation or airport process at the  $i$ -time,  $L_{ji}$  is total water consumption limit.

#### 3.2 Production decision-making level

Target function looks like:

$$W_2 = y \sum_{k=1}^l \sum_{i=1}^n \sum_{j=1}^m Q_{ji}(1 - \overline{k_{ji}})n_{ki} + \sum_{k=1}^p \sum_{i=1}^m p_{ki} \rightarrow \min \quad (2)$$

$$p_{ki} \geq 0, \quad k = 1, 2, \dots, l; i = 1, 2, \dots, n; j = 1, 2, \dots, m;$$

where:  $y$  is an economic evaluation of water in the given region;  $\overline{k_{ji}}$  is the given level of water reuse by the  $j$ -aviation or airport process at the  $i$ -time;  $n_{ki}$  is a multiplicity of water dilution by  $k$  pollution at the  $i$ -time;  $p_{ji}$  are expenses necessary for elimination of  $k$  pollution at the  $i$ -time.

### 3.3 Technological level of decision making

Tasks at this level relate to a class of problems of optimal control of wastewater purification technological processes and are formed taking into account the above-mentioned notation in the following way: let us say a given functional form is as follows:

$$\int_{T_0}^{T_1} [Q^T(t)R(t)Q(t) + U^T(t)R_1^T(t)U(t)]dt, \quad (3)$$

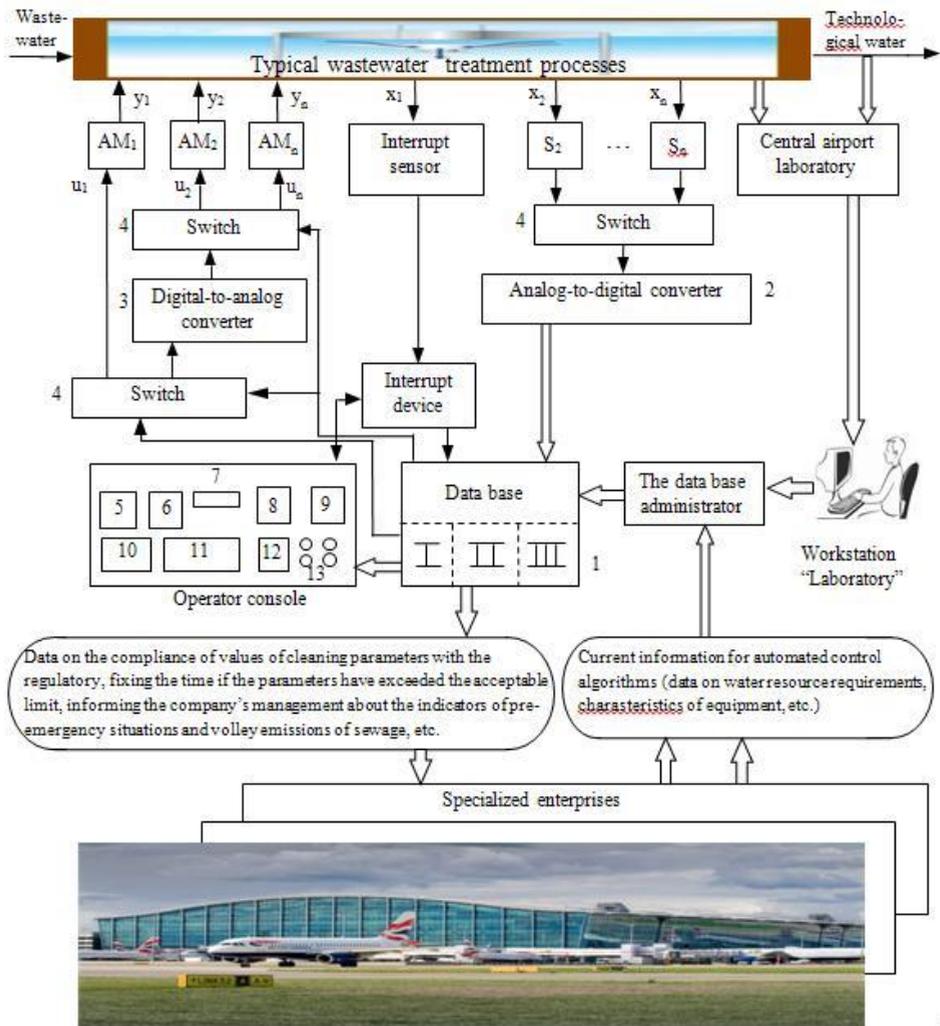
where:  $R$  and  $R_1^T$  are therefore nonnegatively defined matrices and  $U^T(t)$  is the control influences matrix. It is necessary to determine its minimum value for the dynamics of the control object.

In Figure 2 the technical structure of the automated control subsystem of the airport's water-saving processes is presented. The operator's panel provides the following functions:

- display and control of the current state of technological processes of wastewater treatment;
- task control parameters for technological processes of purification and their transfer to the control level;
- warning and emergency alarm;
- reception and display of the results of the rapid analysis of sewage treatment from the automated workstation "Laboratory";
- registration and formation of accounting documents;
- archiving and viewing archival documents.

The automated workstation "Laboratory" can provide, input and transfer to the operator's console up to 50 results of rapid tests of sewage. Technically, the automated workstation "Laboratory" and the operator's panel operate on the basis of personal computers and network operating system. The database is unique to solving a set of tasks at all levels of the management hierarchy.

The information base of Integrated automated control system includes data on the needs of aviation and airport operations water resources, the composition of wastewater, the physical and chemical parameters of the pollution ingredient, the characteristics of reagents and equipment. The above information is formed in the structural subdivisions of the aviation specialized enterprise, as a result of central laboratory research in the form of documents and data on electronic media.



**Fig. 2.** The technical structure of the ACS of the airport's water-saving processes.

Where: I - software of the calendar planning and management subsystem of production air transport processes;

II - software of the automated control subsystem of the airport's water-saving processes;

III - software of the automated control subsystem of technological processes of wastewater treatment.

1 – a control computer; 2 – analog-to-digital converter, ADC; 3 – digital-to-analog converter, DAC; 4 – a switch; 5 – an indicator device; 6 – a recording device; 7 – a display; 8 – digital indicators the parameters of processes of sewage treatment; 9 – a control device used to control the processes of cleaning on the initiative of the operator; 10 – a scheme with the information about the deviation of parameters from the norm; 11 – a remote sensor for changing regulator settings; 12 – a sound communication device; 13 – remote control of wastewater treatment processes; AM – actuating mechanism, IS - interrupt sensor;  $y_n$  – parameters of the technological process of cleaning;  $u_n$  – control influences;  $x_n$  – perturbing input parameters;  $S_n$  – sensors of parameters of processes of the wastewater treatment.

The main arrays of the necessary information are filled in accordance with the requirements of the data structures submitted to the relational data model and coming to

both the operator's console and other subsystems of the airport's Integrated automated control system and the automated control subsystem of technological processes of purification (ACS TP) in accordance with the levels of the integrated automated control system hierarchy.

Applied software for automated solving of optimization tasks, presented above, should be implemented in a high-level programming language. The selected database management system PostgreSQL [13] has support for downloading additional modules for different programming languages. In addition to the functioning of the airport's integrated automated control system, some methods for optimizing security parameters of the system may be implemented based on these programming languages. Proceeding from the tasks of development of the automated control subsystem of the water-saving processes, the most effective is the use of Java programming language with the connection to the corresponding add-in. Such an appropriate module at DBMS PostgreSQL is called "PL / Java" and has the following properties:

- ability to write functions, triggers, user-defined types using the latest versions of Java;
- standardized utilities to install and maintain Java code in a database;
- standardized display of parameters and results. Support for user defined scalar and compound types (UDT), pseudo types, arrays and sets;
- built-in, high-performance JDBC driver that uses PostgreSQL SPI internal procedures;
- metadata support for the JDBC driver. Both DatabaseMetaData and ResultSetMetaData are included;
- integration with PostgreSQL;
- ability to use parameters IN, INOUT and OUT.

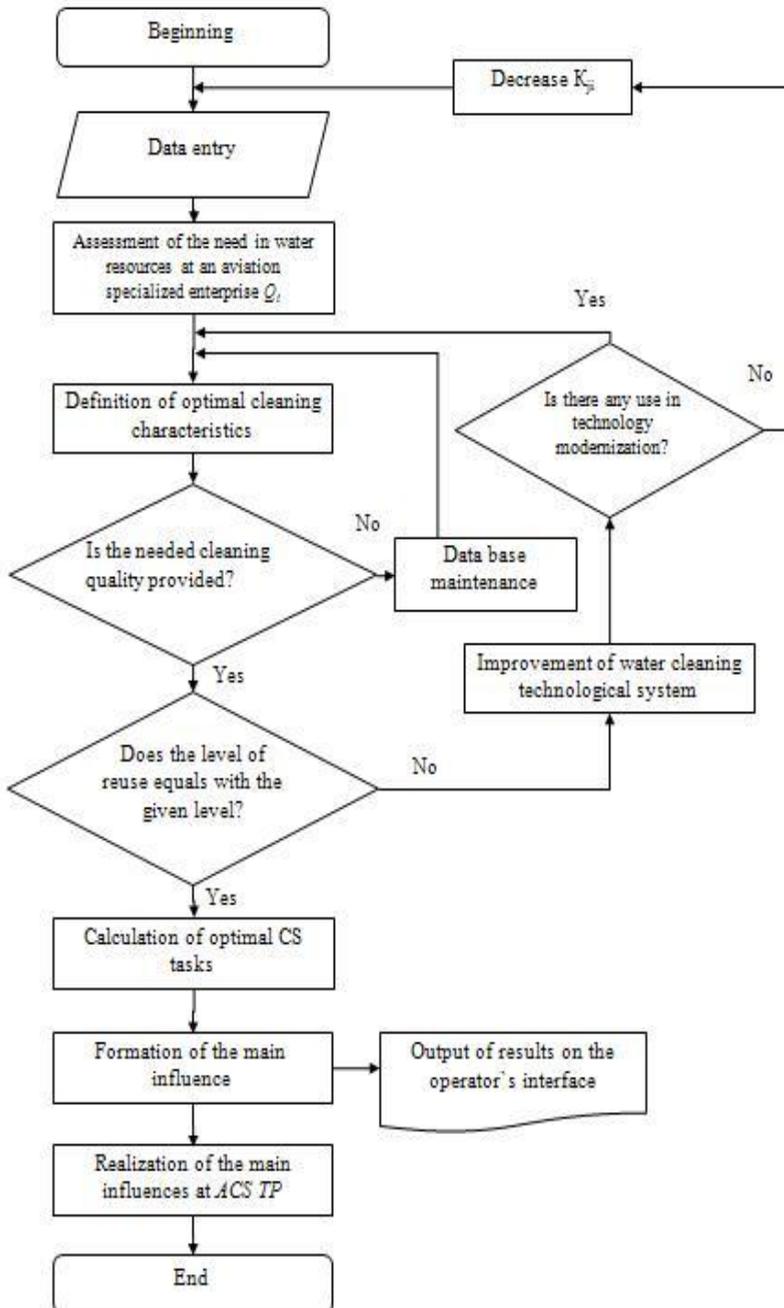
Developing solutions in the Java programming language will provide a number of benefits:

- one of the main benefits of Java language is the ability to transfer programs from one system to another. Since applications in the Java programming language do not depend on the platform at both the source code level and the binary level, they can be run on different systems. It also provides the ability to further integrate solutions into the World Wide Web.
- Ability to create modular programs whose source code can be used multiple times;
- JVM (Java Virtual Machine) is optimized for large multi-core processors and can handle hundreds of data streams without any problems.

## 4 Results

The result of the presented work is the algorithm of rational water reuse, realized in the conditions of functioning of the Integrated automated control system of the airport and given in Figure 3. The assessment of the needs of water resources is carried out at the upper level of airport management (organizational and economic level) in accordance with the mathematical formulation of the optimization task (1). The solution of the task is carried out by the method of linear programming using a set of the calendar planning subsystem applications and management of airport. A distinctive feature of the solving of this task is the water consumption optimization for the normal of the j-aviation and airport operations functioning being carried out taking into account its reuse.

Optimization of the volume of water consumption allows us to assess the necessary conditions for the flow of purification processes, the need for doses of reagents providing the required quality of wastewater purification. In the event that the required quality of cleaning is not provided, further research on the quantitative and qualitative composition of wastewater is necessary. After wards, the database administration updates it. On the basis of the refined input information, the conditions of the process of purification and evaluation of the necessary control influences are reviewed.



**Fig. 3.** A generalized algorithm for the water-saving processes managing of an airport.

If the level of water reuse does not correspond to the given data, then as shown in the algorithm, it is envisaged to improve the technological scheme of purification. This task is solved by the head specialist. The procedure is carried out according to the external contour of the considered algorithm.

After calculating the optimal task of the control system, control influences are formed. These impacts are realized within the automated control subsystem of technological processes of purification and come directly to the technological installation of the purge, as well as to the operator's console. The functional responsibilities of the operator include: control of the cleaned water quality indicators, correction of the control system tasks, control of switching operations.

Algorithms for automated solving of optimization problems (1), (2), (3) should be rationally implemented in a high-level programming language Java. The choice of programming language (PL/Java) for the implementation of algorithmic provision of automated control of the airport's water-saving processes (with appropriate justification) - another result of this work.

Implementation of the considered algorithm within the airport's Integrated automated control system allows to improve the quality of wastewater treatment, having an effective impact on the operations of the aviation specialized enterprise itself and significantly reducing the cost of additional water consumption. The coefficient of water use multiplicity is used to characterize the closed water-reversing (growing) systems.

$n = Q_{zag} / Q_{sv}$ , where:

$n$  is a coefficient of water use multiplicity;

$Q_{zag}$  is a total volume of water consumed by the enterprise [m<sup>3</sup> / hour];

$Q_{sv}$  is fresh water collection plant in the enterprise [m<sup>3</sup> / h].

The higher this coefficient, the better the water supply scheme. For example, at the beginning of the 21st century in the United States, this ratio reached 7.5. Implementation of the presented algorithmic support at the Zhulyany International airport allowed to increase the factor of water use multiplicity twice (from three to six).

## 5 Discussion

During development of technological systems of sewage treatment on the basis of a methodology life cycle programming of systems there appeared elements of new design technology of water-saving systems. As opposed to traditional schemes of the similar technological purification systems, development for the solution of the functional scheme synthesis task and the choice of the type of equipment is carried out at the earlier stages of the design; an analysis of the technological purification system's properties (estimation of damage from harmful emissions for the society, system controllability, sensitivity) is carried out.

In addition, at the control operation stage of technological purification systems, such a task as the organization of the database for an automated control system was solved only in 2017 by A. Zhuchenko, L. Osipa and E. Cheropkin. The wastewater purification control effects and calculation of optimal parameters of the control system were carried out roughly, becoming one of the main reasons for the entry of pollutants into the environment.

Existing systems of automatic control of clearing processes work at the technological level. In changing modes of operations specialized airport enterprises, where the probability of changing the tasks of the control system is rather large, in the absence of clearly formulated control algorithms, they can not cope with their functions, affecting the quality of water resources negatively.

The obtained results on the operation of the software at Zhulyany International airport, developed on the basis of the presented algorithm, confirm the expediency of controlling the airport's water-saving processes based on mathematical statements of optimization tasks at three levels of management.

On the hindrance of further introduction of automated control algorithms for increasing the criterion of water usage multiplicity is that, with today's development of science, quality

control sensors can only measure a limited number of wastewater parameters. Another part of the indicators calculated analytically after the rapid tests requiring some time.

Further development of automated control of similar processes will be associated with the development of information provision and the development of management algorithms for the most common methods of wastewater treatment. In addition, as data on statistical and dynamic characteristics about standard design decisions for typical cleaning processes is accumulated, information of the lower level of the conceptual model of the database will be recorded as sections of the factual database. In the long run, the Automated Information System for managing of airport's water-saving processes will function.

## 6 Conclusions

According to UNESCO studies, production aviation processes are a very intense source of natural water pollution. Therefore, solving the problems of economical water consumption and wastewater purification of airport based on the use of automated control systems is very timely.

The concept of developing an automated system for control over the airport's water-saving processes has been adopted. It's based on the life cycle programming of a technological purification system. And it involves decomposing the original (growing) task both in stages of the life cycle and in control levels. This approach allowed us to propose a logical scheme of tasks, where the sequence and stages of their decision are determined. The aforementioned decomposition of the growing task into a logical set of tasks ensures the solution of the entire task in the class of modern effective methods of modeling and optimization.

The peculiarity of the proposed algorithm for control over the airport's water-saving processes is the consideration of the issue at three levels of airport management: organizational-economic, production and technological. For the specified levels of control, the target functions have been developed that allow optimal management of water-saving processes.

The presented algorithm for controlling the water-saving processes provides adaptation of the purification processes depending on the quantitative and qualitative composition of wastewater, concentration of reagents, parameters of the purification processes. It also takes into account the small life cycle of water use, allowing it to be used not only at the stage of the system operation, but also at the stage of its working out and continuous development.

The further development of automation control facilities will be primarily related to the development of appropriate software subsystems. We made a choice of a programming language (PL / Java) for the implementation of algorithmic support for automated control of water-saving processes. Based on their advantages, it can be argued that the software of the automated control system of water-saving processes of an airport is implemented as a single software platform. This platform allows you to manage on a common information basis with high performance and new automated control subsystem helps to improve, optimize airport water efficiency.

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