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Integrated Automation of Water Disposal in Terms of Interoperability of Monitoring and Control Processes

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***Abstract*—The main regulatory requirements and recommendations for the justification and creation of systems for the integrated automation of processes in various industries are analyzed. A structural and functional analysis of the process control scheme is performed; it is revealed that less than half of the operations are automated (even with the participation of a human operator). The functional intersections of the used manual and automated methods of collecting information and regulating equipment modes are presented, such as those where it is necessary to implement the developed scenarios for increasing observability and controllability in the integrated automation of wastewater disposal systems in populated areas with a critical requirement for their interoperability. It is proposed to use the new generation methodological apparatus of OSTIS Technologies for such purposes.**

***Keywords*—water disposal, monitoring, control, integrated automation, interoperability, OSTIS technology**

I. Introduction

A vital necessity for the development of water supply and sewerage organisations (WSS) is the complex automation of their technological processes, which is a management that provides for the functioning of a production unit (section, shop, enterprise as a whole) as a single interconnected information complex with monitoring and regulation also with human participation [1], [2]. According to GOST 34 (GOST 34.601-90) the creation of automated control systems (ACS) includes the following stages: formation of requirements, concept development, terms of reference, preliminary design, technical design, working documentation, commissioning, maintenance. At the initial stage of creating an ACS it is necessary to conduct a survey of the automation object; on the basis of the obtained data it is necessary to identify the main functional and user requirements for such a product. As a result of the conducted research, an analytical report should be drawn up (GOST 7.32-2001 'Report on research work' can serve as a basis for the creation of the document).

At the same time, this task is extremely difficult from the design stage, because it is necessary to identify potential sources of increasing the intensity and efficiency, reducing the duration of forced downtime, as well as to estimate the amount of necessary capital and operating costs (caused, including abnormal situations) [3]. At the same time, an important component of complex automation is [4]: interfacing (informational and constructive) of systems and equipment; unification of hardware, algorithmic, software, methods and means of maintenance. Within the framework of water supply and sanitation organisations it is difficult to systematise the collection of initial information and to set tasks of coordination of automated technical means and personnel of water disposal complexes [5], as such where the operational observability of parameters is extremely low and the uncertainty of bio-physico-chemical transformations in water solutions is high [6].

II. Structural and functional analysis of wastewater disposal in settlements

Since the key role in the creation of ACS is assigned to the justification and coordination of its architecture, as it should determine the requirements and procedure for the design, development and modernisation (reconstruction) of a single system solution, the structural layout of the wastewater disposal scheme is performed (Fig. 1).

On the basis of expert and calculation assessments [5], [7] it is known that the degree of automation of municipal wastewater disposal at the moment is low (less than 35% of the required) – many control operations are performed by specialists of the enterprises themselves in manual and expert modes (tab. I), while the average level of their qualification at the moment does not meet modern requirements.

When further analysing the functionality of wastewater disposal, at the initial level of generalisation, it is assumed that the processes that are partially automated are fully controllable. At the same time, it is obvious that out of ten (see Table I) monitoring and control subsystems, extremely insignificant part of them (two - three) corresponds to the term 'automatic' (operation without human participation). At the same time, even in such a technological situation, the task of coordination of monitoring and control operations of units and assemblies is acute, which is currently not actually solved within the framework of water supply and sanitation organisations.

III. Interoperability of real wastewater disposal systems in settlements

According to ISO/IEC 24765 interoperability is the ability of two or more systems or components to exchange information and to use the information obtained as a result of the exchange. The problem of interoperability, according to world practice, should be solved on the basis of the use of principles and technologies of open systems, using methods of functional standardisation [8]. Such solutions are standardised by GOST R 55062–2021 'Information technologies. Interoperability. Basic provisions'. To ensure compliance with this standard, any particular solution should be obtained on the basis of a unified approach containing a number of basic stages; it is also necessary to develop a document containing a plan (strategy), as well as a glossary on the problem of interoperability.

Based on the generalised ways of automating (monitoring and controlling) wastewater management (see Table I) we summarised their interactions (Fig. 2).

Systematisation of the operational overlay confirms the critically poor observability and controllability of the processes of the technological complex of municipal wastewater disposal and treatment (see Fig. 2) – there are only six interactions. There is no direct interconnection between individual elements (primarily concerning the processes in sewage pumping stations (SPS) and the sewerage network); there is also no direct data exchange between automated solutions that solve different tasks - information coordination is provided by a human specialist in periodic mode, whose qualifications require significant strengthening. A segment of the [illegible] disposal network is not fully controlled. Based [illegible] author's methods [5], [6], scenarios for [illegible] observability and controllability of such a [illegible] proposed (Table II).

Based on such approaches (see Table II) it is [illegible] to solve the problem of interoperability at [illegible] technical, semantic and organisational [9]. The [illegible] level includes the tasks of interaction between [illegible] and the hardware and software platform on [illegible] hosted. The semantic level reflects those [illegible] that are used by services to establish [illegible] among themselves (clusters of services) and [illegible] Such a task requires the exchange of information [illegible] services concerning their qualities that [illegible] into interaction: it must provide information [illegible] operations they perform in a form that is [illegible] analysed either by the user or by another [illegible] [11]. At the organisational level, in fact, in [illegible] operation, it is a question of implementing the [illegible] of the possibility of providing services to [illegible]

Accordingly, the proposed coordination of [illegible] monitoring and control methods based on the [illegible] of 'interoperability' in complex automation [illegible] specialised methodological apparatus of a [illegible] tion. Such solutions include the OSTIS [illegible] Intellectual computer systems of new [illegible] oped on its basis are called ostis-systems. [illegible] of OSTIS Technology is a universal [illegible] representation (coding) of information in the [illegible] of intellectual computer systems, called SC-[illegible] code texts (sc-texts, sc-constructions) [illegible] semantic networks with basic set-theoretic [illegible] The elements of such semantic networks [illegible] elements (ssuzzles and sc-connectors, which, [illegible] depending on their orientation can be sc-arc [illegible] The universality and unified nature of the SC-[illegible] describing on its basis any types of [illegible] any methods of problem solving, which, in turn, [illegible] simplifies their integration both within one [illegible] within a team of such systems.

The basis of the knowledge base developed [illegible] Technology is a hierarchical system of [illegible] of subject areas and ontologies, among [illegible] universal Kernel of semantic models of [illegible] and methodology of development of [illegible] of knowledge bases, providing semantic [illegible] of developed knowledge bases [13]. The [illegible] ostis-system problem solver is a set of agents [illegible] exclusively by means of specification of the [illegible] processes they perform in the semantic [illegible] agents). All of the above principles together [illegible] sure semantic compatibility and simplify the [illegible] of various components of computer systems, as [illegible] such systems themselves, which is in demand [illegible]

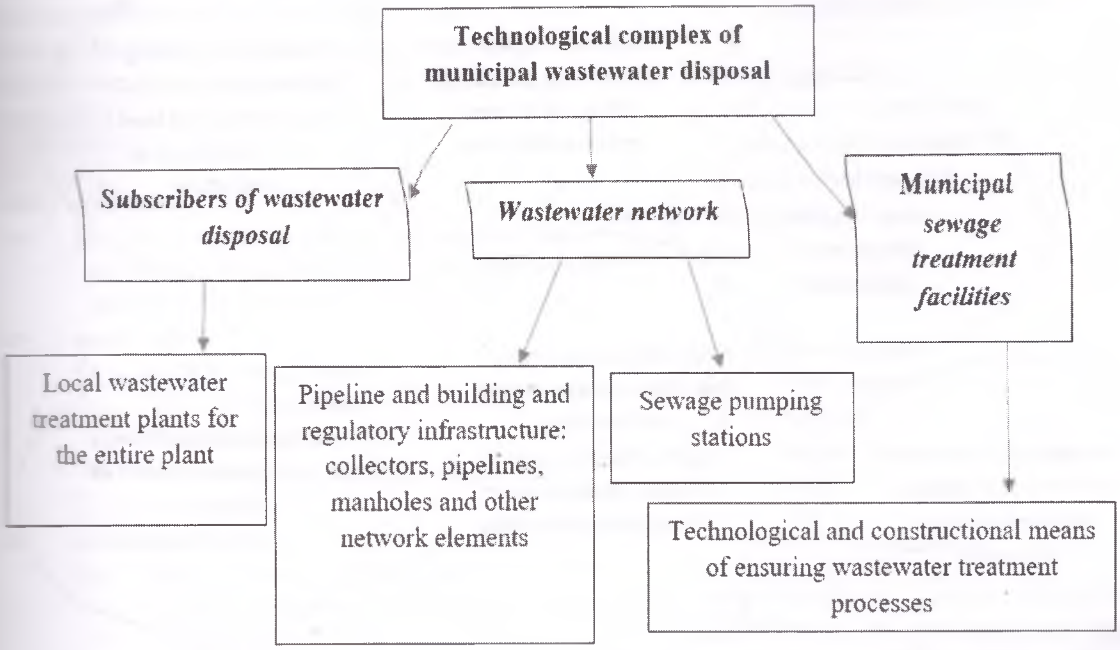

Figure 1. Generalised structure of the wastewater disposal system of settlements

Table I
Analysing the monitoring and management processes of the wastewater system

Point No.	Description of monitored indicators	Monitoring and management solutions used
1	Condition of local pipelines and construction and regulatory infrastructure of wastewater network subscribers	Personal diagnosis and manual handling
2	Efficiency of wastewater treatment at local treatment plants (LTP) (if any): compliance of quality indicators of discharged wastewater with the requirements of maximum permissible concentrations (MPC) of pollutants	Monitoring and control are partially implemented in automated mode
3	Resource costs of localised wastewater treatment: electricity, reagents and other consumables	Monitoring and management are partially implemented in automated mode (performed at the end of the reporting period)
4	Condition of local treatment plant (LTP) equipment (if any)	Monitoring is partially realised in automatic mode
5	Compliance of quality indicators of discharged wastewater of controlled subscribers with the requirements of MPC of pollutants	Personal diagnostics – performed by by specialists of water supply and sewerage organisations
6	Wastewater quality indicators in the wastewater network: from the control well to the entrance to the municipal sewage treatment plant (STP)	Not fulfilled
7	Condition of equipment and premises of sewage pumping stations of the wastewater disposal network, their piping and building and regulatory infrastructure	Monitoring is partially automated
8	Efficiency of wastewater treatment at municipal WSCs: compliance of treated wastewater discharged into water bodies with the requirements of regulatory documents	Monitoring and control are implemented in automated mode (dispatching)
9	Resource costs of wastewater treatment at municipal WSCs: electricity, reagents and other consumables	Monitoring and management are partially implemented in automated mode (performed at the end of the reporting period)
10	Condition of equipment of municipal WSCs, their pipeline and construction and regulatory infrastructure, including aeration system with blower stations, disinfection modules and reagent farms	Monitoring is partially realised in automatic mode

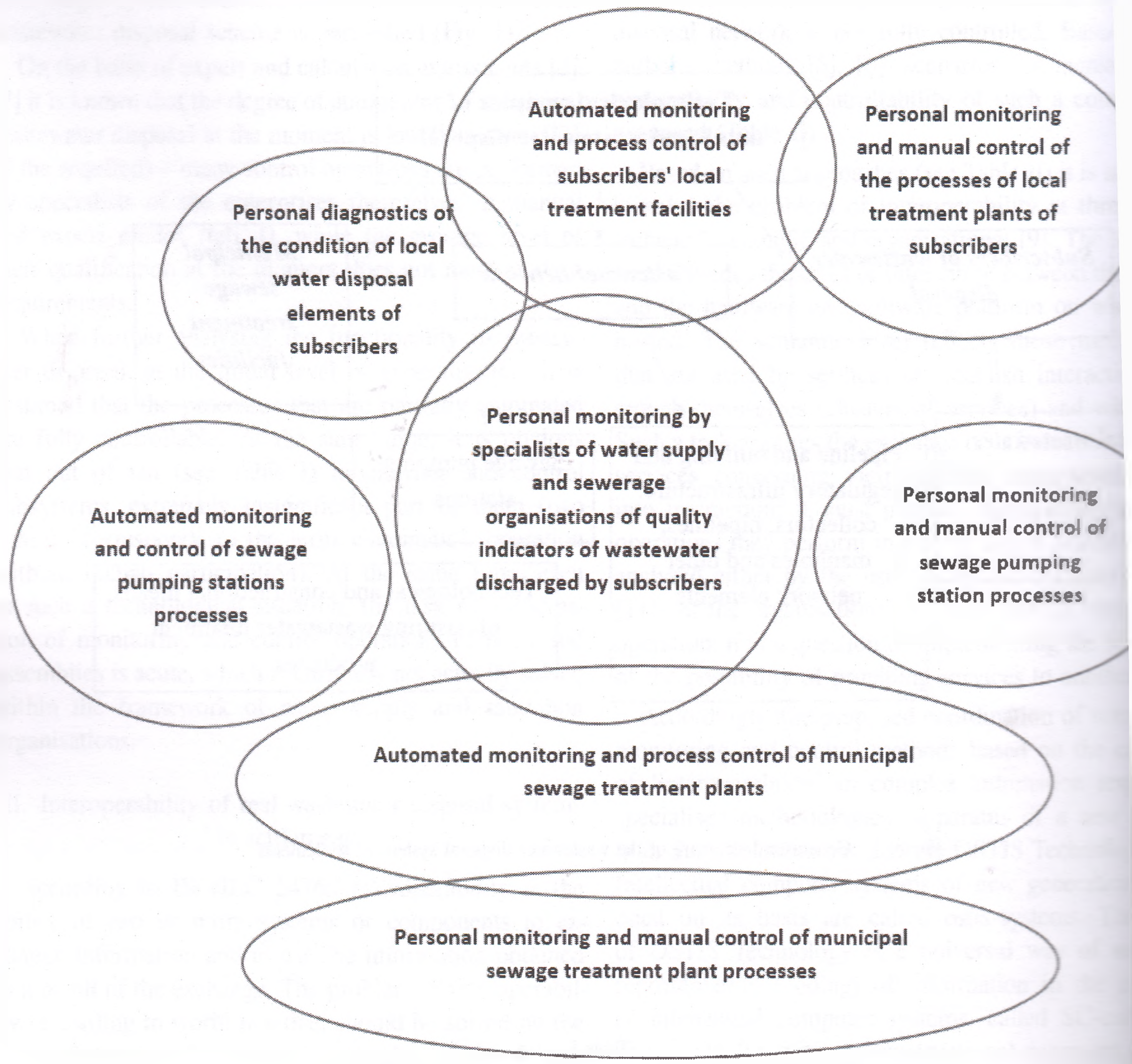

Figure 2. Scheme of interaction between monitoring and management of wastewater disposal (intersection of solutions means their in

Table II

Scenarios for increasing observability and controllability in integrated automation of wastewater disposal systems in settlements

Minimum scenario	1. Systematisation on the basis of a single platform of all primary and calculated parameters. 2. Systematisation on the basis of a single platform of all used models. 3. Systematisation on the basis of a single platform of all algorithms used. 4. Formation on the basis of the platform of a single circuit of technological monitoring and control (with the formation of an up-to-date knowledge base with the function of training personnel on site) according to the criteria of 'resource efficiency', 'reliability', 'environmental safety'
Medium scenario	1. Performing a 'minimal' scenario. 2. Creation and implementation of new integrated models and algorithms for monitoring and management on the basis of a single platform. 3. Installation of additional measuring equipment, including for indirect assessment of parameters of the technological complex of wastewater disposal and treatment. 4. Creation of laboratory modelling information systems (LIMS). 5. Creation and implementation of new integrated monitoring and management strategies based on a single platform
Optimistic scenario	1. Performing an 'average' scenario. 2. Obtaining data on subscribers 'dangerous' for the WSC; installation of additional measuring devices in this system, including for indirect assessment of parameters of the technological complex of water disposal and wastewater treatment. 3. Creation and implementation of new integral models and algorithms for subscribers 'dangerous' for the water utility. 4. Creation and implementation of new integrated monitoring and management strategies based on a single platform.

organisations.

Using SC-code, a number of top-level ontologies have been developed for the sphere of housing and communal services, describing the most common concepts. Let us consider several fragments of these ontologies in the SC code [13].

utility equipment
≔ [totality of technical devices and systems ensuring functioning of engineering infrastructure of apartment buildings and municipal facilities]
⇒ *subdividing**:
{• *plumbing equipment*
• *electrical equipment*
• *heating equipment*
• *accounting and analytical equipment*
}
⇒ *subdividing**:
{• *main technological equipment*
• *auxiliary equipment*
• *emergency equipment*
• *test equipment*
}
⇒ *explanation**:
[A complex of mechanical, electrical and electronic devices that ensure the supply of communal resources (water, heat, electricity) and the safe operation of the housing stock. Includes both traditional engineering equipment and modern intelligent control systems.]

shut-off valves
≔ [a technical device for controlling the flow of a working medium by changing the area of the flow cross-section]
⇒ *subdividing**:
partitioning by design
= {• *gate valve*
• *flap*
• *tap*
• *vent*
• *valve*
}
⇒ *possible material**:
• *cast iron*
• *carbon steel*
• *stainless steel*
• *brass*
• *bronze*
• titanium
• *polymer*

suspended solids
≔ [complex compounds of organic and inorganic substances suspended in water]
⇒ *subdividing**:
{• *organic suspended solids*
• *inorganic suspended solids*
}
⇒ *areas of application**:
{• *wastewater treatment*
• *water quality monitoring*
}
⇒ *parameters**:
{• *concentration*
• *particle size*
}
⇒ *operating principle**:
{• *sedimentation*
• *filtration*
• *coagulation*
}

Conclusion

As a result of structural systematisation of the wastewater disposal scheme, the key subsystems (subscribers, wastewater disposal network, sewage treatment plants) were identified, and the analysis of the methods of monitoring and control of technological processes used in them substantiated the conclusion that their automation is extremely low. The degree of overlap between manual and automated monitoring methods is significant and requires mandatory compliance with the interoperability criteria within the created scenarios (minimum, average, optimistic) for increasing the observability and controllability of wastewater disposal in settlements – it is necessary to state separately that a unified technological ecological environment has not been created in WSS organisations at the moment.

Justified to overcome such a significant problem is the use of OSTIS Technology, the basis of which is a universal way of semantic representation (coding) of information in the memory of intelligent computer systems, called SC-code. The fundamental results obtained with its use will make it possible to implement digital transformation of the housing and communal services (including at the state level) along the chain: 'wastewater disposal' – 'water supply and wastewater disposal' – 'water supply and sewerage facilities as a whole' – 'housing and communal services as a whole' on the basis of fulfilling the criterion of interoperability of systems, where it is necessary to take into account the human factor and the need for significant improvement of staff qualification.

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КОМПЛЕКСНАЯ АВТОМАТИЗАЦИЯ ВОДООТВЕДЕНИЯ В РАЗРЕЗЕ ИНТЕРОПЕРАБЕЛЬНОСТИ ПРОЦЕССОВ МОНИТОРИНГА И УПРАВЛЕНИЯ

Войтов И.В., Штепа В.Н., Охтилев М.Ю., Муслимов Э.Н., Россоха Е.В.

Проанализированы основные нормативные требования и рекомендации к обоснованию и созданию систем комплексной автоматизации процессов разноотраслевых объектов. Выполнен структурный и функциональный анализ схемы технологического управления: выявлено, что автоматизированы (даже с участием человека-оператора) менее половины операций. Представлены функциональные пересечения используемых ручных и автоматизированных способов сбора информации и регулирования режимами оборудования, как такие, где необходимо реализовывать разработанные сценарии повышения наблюдаемости и управляемости при комплексной автоматизации систем водоотведения населённых пунктов с критическим требованием к их интероперабельности. Предложено для таких целей использовать методологического аппарата нового поколения Технологии OSTIS.

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