Development of Automated Monitoring and Management System of Municipal Solid Waste Landfill Based on the Industrial OMRON Controller

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Abstract. The application of the programmable logic integrated circuits (PLC) for creating the software and hardware complexes of the medium complexity is an economically sound solution. The application of the OMRON controller to solve the monitoring and management tasks of safety of the municipal solid waste (MSW) landfill with the use of technology of the filtrate recirculation and the landfill maps irrigation is shown in the article. The article contains the technical solution connected with the implementation of the 2162059RU invention patent for the municipal solid waste landfill management in the Kurgan region of Russia. The calculation of maps and ponds was made with consideration of the limited sanitary and protection zone. The GRUNDFOS dosing and reactor equipment was proposed to use in the project.

1. Introduction
The municipal solid waste landfills (MSW) are the source of the long-term negative impact on the environment [1]. Despite the fact that the municipal solid waste landfills have a limited operating period (an average of 30 years) after its closure and reclamation the complete life cycle of this natural and technical system lasts for thousands of years during which the emission products hazardous to the environment will be released [2]. Qualitative determination of energy potential and methane generation from municipal solid waste (MSW) was considered in the article [3]. Therefore it is relevant to formalize the generalized models of the process management at the municipal solid waste landfills with consideration of the analysis of the material-energy and information flows and to develop the algorithms for the structural-parametric synthesis and the automatic control for setting up an automated monitoring and management system of the municipal solid waste landfills. Now the operational management of the waste recycling process at the landfills in Russia is almost not used which justifies expediency of the development of the control automation system of the municipal solid waste landfill [4].

The monitoring and analysis of the environmental status of the municipal solid waste landfill incorporated in the software and technical solutions of the management provide the operational control over the processes occurring at the given facility. The complex automated system of the landfill management will significantly improve the monitoring quality. The modular construction of the system will provide the flexibility of the structural implementation with the possibility of the maximum consideration of the individual characteristics of the region where the municipal solid waste landfill is located. The application of this software product will provide the informational support throughout the life cycle of the municipal solid waste landfill and increase the management efficiency and its operation safety.
2. Material and methods of the research
When justifying the methods and algorithms of the management of waste depositing objects, the
methods of system analysis, the general theory of systems, the theory of automatic control, the methods
of mathematical and simulation modeling were used. Considered as objects of the modeling and
management, the material-energy and information flows occurring at the waste recycling facilities were
the object of research.

3. The results of the study and their discussion
According to the functional feature, the projected system is logically divided into five modules
representing design, technological and management solutions in the life cycle of the landfill. The design
module is designed to calculate the main parameters of the landfill, which also includes the dynamics
of emission flows of the filtrate and biogas. The automated information processing module is an
automated workplace of the polygon controller. The ASUTP module is designed for automated control
of the technological process at the landfill MSW.

3.1. Schematic diagram and algorithm for polygon management
The purpose of the work was the development of technical solutions for the use of patent 2162059 RU,
aimed at managing local treatment facilities of the landfill. As a hardware, a programmable Omron
controller was chosen, which is a compact product for solving automation problems of low and medium
complexity. The use of Omron controller software also allowed the development of a human-machine
interface for managing local wastewater treatment facilities for the MSW landfill [5].

The automated system of operational control included the following components: control of the
sections of the landfill by recirculation of the leachate; pH adjustment stage, also purification of the
leachate and surface waste on hydrobiological sites is also proposed [6, 7]. The scheme of automation
of local structures of the solid waste landfill is shown in Figure 1.

The landfill consisted of two maps (sections). Local treatment facilities for neutralizing the leachate
are represented by a storage pond-averageizer and a settling pond. To stabilize the moisture content of
the solid waste landfill, an algorithm has been developed that implements the management of processes
at the MSW landfill with feedback. To accelerate the stabilization of the pH environment, the necessary
amount of lime solution added to the recycled filtrate is calculated, depending on the pH of the solid
waste massif and the volume of the recirculated leachate (Figure 1). From the maps of the landfill, the
leachate enters the accumulation pond-averageizer, consisting of three sections connected by locks. Drivers
for and against municipal leachate recycling was considered in the article [8]. According to this scheme,
the leachate formed in section 1 of the waste disposal site of the landfill (and later in section 2 of the of
the landfill will be fed to section 1 of the accumulation pond-averageizer. When the 1 section is filled, the
leachate will flow over into the 2 section of the accumulation pond-averageizer, and then to the 3 section
of the accumulation pond-averageizer.

By the pump (H1) the leachate from the collecting pond sections is fed to the neutralization station
consisting of three vessels: a reaction chamber (TU) where also a prepared lime solution from the tank
will be supplied. The scoop is driven by a screw with an electric drive to a dilution with a water pump
(H3). Then the prepared solution of Ca(OH)\textsubscript{2} will be sent to the vessel (ND). Then the solution of Ca
(OH)\textsubscript{2} is fed to the reactor-mixer. All tanks are equipped with mixers. In the reactor-mixer, a constant
pH value of 9 is maintained using an automatic control system, which will allow automatic pH-regulation of the effluents at the outlet of the mixer. After processing the effluent, they enter a
sedimentation pond. In the settling pond, the pH will be controlled by the pH meter (pH4), the pH of the
filtrate coming from the I–II sections of the landfill waste, pH meters, pH1 and pH6 respectively. When
the pH of the leachate arrives from the landfill sites of the values typical for 10–15 years of operation
of the landfill site, the leachate will be fed directly from the pond-averageizer by the H1 pump to the settling
pond (in Figure 1 as a dashed line).
Figure 1. Scheme of automation of local structures of solid domestic waste: F1–F9 – consumption; B1–B6 – the adjustable valve.

Irrigation of the polygon maps is made by filtrating from the settler pond at a pressure of 1–2
atmosphere through perforated pipelines with a diameter of 1.5–2" based on the required flow rate. Software control of the technological mode is to maintain and reduce the deviation from the specified process. Physical and chemical quantities are monitored. The algorithm for controlling the technological process was previously described in [8].

When choosing a reactor station, the metering equipment of GRUNDFOS was considered. The dosing equipment is connected to the general control system of local facilities of the landfill. With the help of the pump H3, the reagent preparation tank (TU) is filled with water, the required amount of dry reagent is filled, after which the mixer M1 is turned on until the powder is completely dissolved. Then the prepared solution is pumped to the dosing container (ND). In the dosing tank, the agitator works continuously to maintain undissolved particles in a suspended state. The filling of the reactor (EP) occurs in an automatic mode. The system tracks the upper and lower levels of the liquid in the tanks. When the reactor (EP) is filled, the microcontroller monitors the pH in real time and deviates from the set one, gives a command to the pump dispenser, which brings the pH level to the preset level. When the required pH is established, the reactor is emptied and the treated effluents are fed to a settling pond.

3.2. Development of technological scheme, implementing patent for invention No. 2162059 RU
Programming of the algorithm of the technological scheme is carried out with the help of the PLC Omron.

The station of the operator controller of the landfill site includes the following modules:
- Sensor monitor of the operator of control of local structures;
- Programmable Omron microprocessor.

The dosing station is a separate standard industrial module and has its own control panel. The control program for the Omron controller is written in the language of Ladder diagram (LD) (standard IEC...
Language LD is a software implementation of electrical circuits based on electromagnetic relays. The program in the language of LD has a clear and intuitive graphical interface, representing logical operations as an electrical circuit with closed and open contacts. The CX-Programmer Support Software is equipped with an SFC editor, and can be used to create, monitor, and debug SFC programs for CS/CJ-series and CP-series PLCs. The CX-Programmer supports SFC language in addition to conventional ladder and structured text (ST) programming languages. The main blocks of the developed program and a brief explanation of the blocks are shown in Figure 2 [9].

![Ladder diagram](image_url)

**Figure 2. Ladder diagram.**

The filling of the lime milk preparation tank is described in the first section (see Figure 2). Automatic activation of the pump H3 when emptying the tank (TU), checking the conditions for the presence of clean water, the bay to the upper level of the capacity of the EP; manual control from the operator panel – contact 4.00 (see Figure 2). The process of controlling the dosage of the Ca(CO)\textsubscript{2} in the second section. The control of the mixer shows the third section [10]. The operator panel (touch screen) is designed using the CX-Designer (Omron) program. The dialog box for the operator of the local leachate decontamination facilities contains a duplex control screen (Figure 3) and monitoring of physicochemical parameters.
Conclusions
The application of the industrial Omron controller and the CX-Programmer and CX-Designer software complex showed the feasibility and flexibility of the implementation with the use of technology of the leachate recirculation and the MSW landfill irrigation.

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Figure 3. Touch screen monitor recirculation system control leachate.