Three-Loop Automatic of Control System the Landfill of Household Solid Waste

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Abstract. The analysis of models of governance ground municipal solid waste (MSW). Considered a distributed circuit (spatio-temporal) ground control model. Developed a dynamic model of multicontour control landfill. Adjustable parameters are defined (the ratio of H₂, CO₂ emission/fluxes, concentrations of heavy metals ions) and control (purging array, irrigation, adding reagents). Based on laboratory studies carried out with the analysis of equity flows and procedures developed by the transferring matrix that takes into account the relationship control loops. A system of differential equations in the frequency and time domains. Given the numerical approaches solving systems of differential equations in finite differential form.

1. Introduction

Landfill is a complex biochemical system in which the flow of interrelated physical, mechanical, chemical, and biological processes happen [1]. The establishment of a system for managing ground MSW as a bioreactor with several adjustable values, is a challenge. Distributed management model single contour landfill MSW was reviewed in [2] (Figure 1).

![Figure 1 – Block diagram of a generic distributed control landfill MSW](image-url)

- $\omega_\theta(\xi, \tau)$ – humidity condition in the array specified wastes;
- $\omega(x, t)$ – deviation from the specified output distributed;
- $\overline{\omega}_x(x, t)$ – distributed control;
- $\overline{\omega}_b, (x, t)$ – external perturbations;
- $\overline{\omega}(\xi, \tau)$ – standardizes function.
The aim of this study was to investigate the influence of physico-chemical parameters of MSW landfill on the resulting emission products (filtrate and biogas) and development of a multi-circuit control system in multidimensional control systems, unlike the one-dimensional, outage one of the loops can occur due to changes in other circuits.

2. Main factors that describe the dynamics of an object
Depending on external factors (age, physical-chemical processes) the object's State is characterized by steady or transient modes, which has changed management requirements object [2]. Available managed parameters monitoring processes in the array of MSW, suggested to use: purge air waste array hydration (leachate recirculation) and the addition of reagents to the array. Thus, the adjustable parameters will be: 1 – the presence of oxygen in the body of the landfill (B); 2 – humidity MSW array \( \omega \); 3 – strong response (pH).

3. Block diagram models of multi-circuit control systems testing ground
For building control system ground MSW were used the system of linear differential equations or corresponding images by Laplace in the frequency domain of the complex variables [3]. Figure 2 shows a block diagram of a multi-dimensional system of regulation in landfill processes, including the systems with perturbations of the \( k \), \( l \)-offices (\( l = 3 \)) and \( m \)-observations (exits, \( m = 3 \)) dependence (1):

\[
y(s) = G(s)u(s) + G_d(s)d(s),
\]

where \( d(s), u(s), y(s) \) are vectors of indignation, management and exit, respectively

\[
d(s) = \begin{bmatrix} d_1(s) \\ d_2(s) \\ \vdots \\ d_k(s) \end{bmatrix}; \quad u(s) = \begin{bmatrix} u_1(s) \\ u_2(s) \\ \vdots \\ u_3(s) \end{bmatrix}; \quad y(s) = \begin{bmatrix} y_1(s) \\ y_2(s) \\ \vdots \\ y_3(s) \end{bmatrix};
\]

\[
G(s) = \begin{bmatrix} g_{11}(s) & g_{12}(s) & g_{13}(s) \\ g_{21}(s) & g_{22}(s) & g_{23}(s) \\ g_{31}(s) & g_{32}(s) & g_{33}(s) \end{bmatrix},
\]

\[
G_d(s) = \begin{bmatrix} g_{11}^d(s) & g_{12}^d(s) & \cdots & g_{1k}^d(s) \\ g_{21}^d(s) & g_{22}^d(s) & \cdots & g_{2k}^d(s) \\ g_{31}^d(s) & g_{32}^d(s) & \cdots & g_{3k}^d(s) \end{bmatrix}.
\]

Formation of control action of \( u(s) \) will be determined by multidimensional controller \( G_c(s) \) taking into account the mismatch errors

\[
\varepsilon(s) = y^*(s) - y(s),
\]

where \( \varepsilon(s) = [\varepsilon_1(s), \varepsilon_2(s), \varepsilon_3(s)]^T \).

Multidimensional controller \( G_c(s) \) is represented by a diagonal matrix types (elements of \( g_{il}(s) \) corresponding to an one-plane metric (one-dimensional) regulators set certain control Act)

\[
G_c(s) = \begin{bmatrix} g_{11}(s) & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & \ddots \\ 0 & \cdots & 0 & g_{nk}(s) \end{bmatrix}.
\]
4. Physical modelling

4.1. The laboratory plant biodegradation of waste

Laboratory installation was performed in the form of reactor simulating on the body of MSW landfill waste management of certain morphological structure [4,5]. Reactor allowed to regulate water-air regime of array wastes (Figure 3).

Figure 3 – Schematic control laboratory installation: —— purge array of MSW; - - - leachate recirculation; Ca(OH)$_2$ – filing of limy milk

Challenge of studies was to assess the degree of biodegradation of waste within the reactor. In order to accelerate the biodegradation of waste there was carried out at the expense of the reactor control irrigation stabilized the seep liquid canister with the addition of lime milk and purge air. The main parameters measured were physical and chemical values: pH, concentration of ions of heavy metals, ammonia nitrogen in leachate, volume of leachate and landfill waste moisture content [6,7].

4.2. Study to determine the optimum parameters of biodegradable waste

Ratio control actions (u) and monitoring parameters of emission flows shown in Table 1.
Table 1 – Control actions and monitoring emission streams

| №  | Control actions, u | Observable options, y                  |
|----|-------------------|---------------------------------------|
| 1  | Purge array       | CH₄/CO₂ Ratio                         |
| 2  | Irrigation        | pH                                    |
| 3  | Adding Irrigation | Reagents concentration of heavy ions  |

Research results have shown that the optimal physico-chemical parameters of the array are:
1 – The presence of oxygen and filling the pores of the landfill body air (B) (Air/water) – 40/60 %;
2 – humidity MSW array (ω) – 60%; 3 – strong response (pH) – 8-9.5.

4.3. Study the interrelations of the multidimensional control tasks

In the synthesis of multidimensional control systems, a great problem difficulties linked to static and dynamic cross-linkages array between different inputs and outputs - R system. Research links control actions used to input the step signals that represent inertial link of the first order [8].

Experiment on research of mutual influence, irrigation and limy milk processing (Figure 4) with stepped change of control actions showed that the humidity was most important (space) factor that affects the amount of air pores and pH; purge provided effects on pH (Figure 5) [9, 10].

Thus the transfer matrix (3) were not considered unimportant connection:

\[
G(s) = \begin{bmatrix}
g_{11}(s) & 0 & 0 
g_{21}(s) & g_{22}(s) & 0 
g_{31}(s) & g_{32}(s) & g_{33}(s)
\end{bmatrix}
\]  

(6)

Figure 4 – Scheme of the experiment on research of mutual influence, irrigation and processing of limy milk, R-cross-connection control actions

Figure 5 – Distribution of dominant factors: moisture content, availability of oxygen (air), pH

5. Mathematical model of ground MSW

Equivalent model (model of the complex variable s (1)) of a linear system is a model in the temporary area
\[ \frac{dx}{dt} = Ax + Bu + Ld, \]
\[ y = Cx, \]
\[ x(t_0) = x_0. \]

(7)

where \( x \) – \( n \)-dimensional State vector; \( d \) – \( k \)-dimensional vector perturbations; \( u \) – \( m \)-dimensional vector offices \((m = 3)\); \( y \) – \( l \)-dimensional vector of observations \((l = 3)\).

The matrix \( A \) is State, \( B \) – offices, \( C \) – observations and \( L \) – perturbations related dimensions:

\[ A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \quad B = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{m1} & b_{m2} & \cdots & b_{mn} \end{bmatrix}, \]

(8)

\[ C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ c_{31} & c_{32} & \cdots & c_{3n} \end{bmatrix}, \quad \Gamma = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1n} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{kn1} & \gamma_{kn2} & \cdots & \gamma_{knn} \end{bmatrix}. \]

(9)

An algorithm for solving problems (1–9) is reduced to the determination of the transfer function of the object (6), the transformation equations of frequency to the staging area. For computer simulation process multidimensional process control system requires conversion of differential equations to discrete finite differential form.

6. Conclusions
The work solved is an ongoing challenge, who in the development of the automated system of state management, landfill and the main results were obtained:

1. Relationship between reference and Identified internal factors affecting the state of the landfill that allowed the development of a transfer matrix, taking into account the cross-connection control loops of the landfill.
2. A system of linear differential equations in the frequency and time fields that implement the multicontour control system of the landfill.
3. Given the numerical approaches solving systems of differential equations infinite differential form.

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