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To cite this article: S N Kostarev *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **537** 062028

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Development of an automated system for integrated environmental monitoring of a municipal waste landfill

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Abstract. The necessity of developing a model for monitoring emissions and discharges from a municipal solid waste landfill at the border of the sanitary protection zone is substantiated. An integrated model for monitoring the state of atmospheric pollution has been developed, taking into account the forecast calculation of emissions and operational monitoring. A truth table was compiled for determining the states of the MSW polygon. A minimization of the disjunctive normal form was carried out using Karnaugh maps, a relay-contact scheme of automated environmental monitoring of the sanitary protection zone of MSW landfills was constructed. An automated operator workplace has been developed using the Omron hardware and software system. Numerical calculation of emissions of impurities into the atmosphere are carried out with the help of Ansys Workbench.

1. Introduction

The organization, systematic observation and control of environmental pollution from municipal waste landfills is the daily goal of environmental authorities. The size of the sanitary protection zone (SPZ) of municipal waste landfills is defined in sanitary regulations and standards 2.2.1/2.1.1.1200-03, which does not take into account the capacity of the municipal waste landfill. However, the load and impact on the environment of a high-loading landfill compared to less loaded will extend over longer distances and for a longer time even after its reclamation, at the same time, for small landfills of MSW, a design calculation of the impact zone of such landfills is required to clarify and justify the SPZ.

2. Equipment and devices used in the studies

The theoretical part of the article was developed using the General systems theory and the theory of Finite-state machine, mathematical and simulation methods. In practical implementation the authors



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use the microcontroller OMRON. We study monitoring and control of microclimate with the OMRON CX-Programmer version 7.1 and CX-Designer software version 2.1.

3. The results of the study and their discussion

According to the current version of sanitary regulations and standards 2.2.1/2.1.1.1200-03 [1], the estimated size of the sanitary protection zone (SPZ) for all solid household (municipal) waste landfills is 500 m and for a longer time even after its reclamation, although this fact has not yet been taken into account when justifying the SPZ at high-loading MSW landfills.

3.1. Development of an integrated monitoring system for emissions of MSW landfills

Comprehensive monitoring should include: an environmental monitoring and monitoring system; environmental conservation forecast of the environment; systems of operational monitoring of the facility and the population living in the area in the residential area.

The goals of monitoring environmental is to control to the environmental state in the zone of influence of the construction and operation of MSW landfills by collecting measurement data, their integrated processing and analysis, to assess the situation and make management decisions. Monitoring includes three stages of work: 1) background monitoring (assessment of the state of natural components prior to construction); 2) monitoring of changes in the state of natural components during the construction period; 3) monitoring of ongoing changes in the state of natural components during the operation of the construction object.

3.2. Predicted emission calculations for pollutants

Several methods are known for modeling emissions from MSW landfills: solution of diffusion and Navier-Stokes [2], Land Gem [3]. There is an approved methodology of the Russian Federation for estimating concentrations in the air of harmful substances contained in emissions of enterprises. Calculations were carried out for atmospheric pollution of the main substances performed in accordance with [4], using a unified program for calculating atmospheric pollution UPRZA "ECO Center".

3.3. Numerical modeling of pollution emissions was carried out using the program ANSYS

In accordance with the developed physicochemical model, numerical modeling was carried out, which is based on the laws of conservation of mass, momentum, energy and is closed by the equations of state of an ideal compressible gas and turbulence, as well as by initial and boundary conditions. The following assumptions are formulated: the flow is considered single-phase, the process of dispersion of CO_x pollution in the atmosphere is taken into account. Figures 1 and 2 show the boundary conditions for the domains [5,6]. When forming a physical model, the effect of gravity was not taken into account as an accepted assumption. In the context of these studies, the task of analyzing the gas-dynamic characteristics of the dispersion flow of CO_x pollutants in the atmosphere from an array of waste of the landfill was considered [7]. The model contained a solid region and a ring region, which represented the boundary of the atmosphere monitoring.

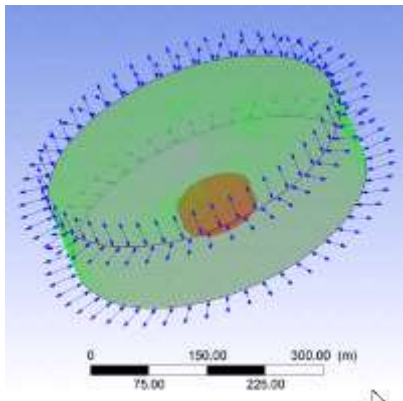


Figure 1. Creating boundary conditions for the Atmosphere domain.

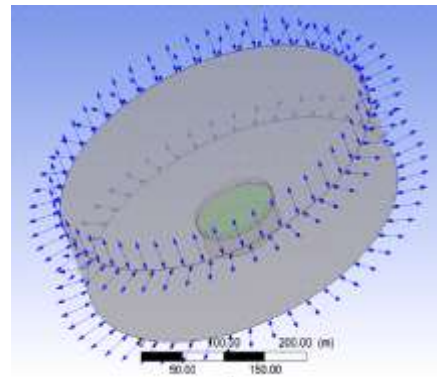


Figure 2. Creating boundary conditions for the MSW and Atmosphere domains.

The design is three-dimensional, its model and grid model are built using the means of Ansys Workbench. MSW and Atmosphere domains were created. The simulation of non-stationary simulation in ANSYS CFX-Pre (figure 3) was carried out.

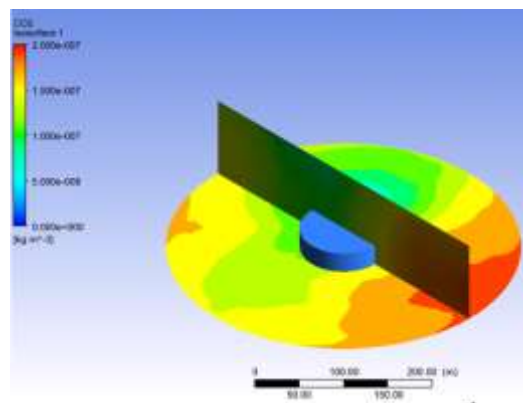


Figure 3. Isosurface CO_x dispersion.

3.4. Development of a combination automat for assessing the safety of emissions of pollutants into the atmosphere

To create a ladder circuit, you need a certain number of input and output signals for operation, and the address of the contacts presented in Table 1.

Table 1. Designation of logical elements of the system.

Signal	Address	Explanation	In / Out
1. G	CH ₄ : 0.00, CO: 0.01	Gaseous substances	In
2. T	1.10	Time	In
3. Y _{Safe}	100.00	Safe condition	Out
4. Y _{Dang.}	100.01	Dangerous condition	Out
5. Y _{Inc.}	100.02	Incident	Out

To extract the Minimal disjunctive normal form (MDNF) of a logical function established by the relational table, one should make the simplest conjunctions of all variables for each row of the table in

which the function is 1. To find a safe state, one should look for minimization of conjunctive normal form (MCNF). Based on the conditions of logical expressions, we construct a truth table. Table 2 shows the truth table:

Table 2. Table of truth of gaseous substances.

Gases (G)	Given time (t)	Safe state (Y_{Safe})	Dangerous state ($Y_{Dang.}$)	Incident ($Y_{Inc.}$)
0	0	0	0	0
0	1	0	0	0
1	0	1	1	0
1	1	1	0	1

To obtain the logical equations of the equipment operation, we obtained a minimal disjunctive form using Karnaugh maps (Tables 3–5).

Table 3. Karnaugh Map (Safe Status).

t	0	1
G	0	1
0	0	1
1	1	1

Table 4. Karnaugh Map (Dangerous Condition).

t	0	1
G	0	0
0	0	0
1	1	0

Table 5. Karnaugh Map (Incident).

t	0	1
G	0	0
0	0	0
1	0	1

$$y_{Safe} = \bar{G}$$

$$y_{Dang} = G \wedge \bar{t}$$

$$y_{Incident} = G \wedge t$$

Based on the obtained logical equations, a relay contact circuit was developed using the Omron software / hardware complex (figure 4).

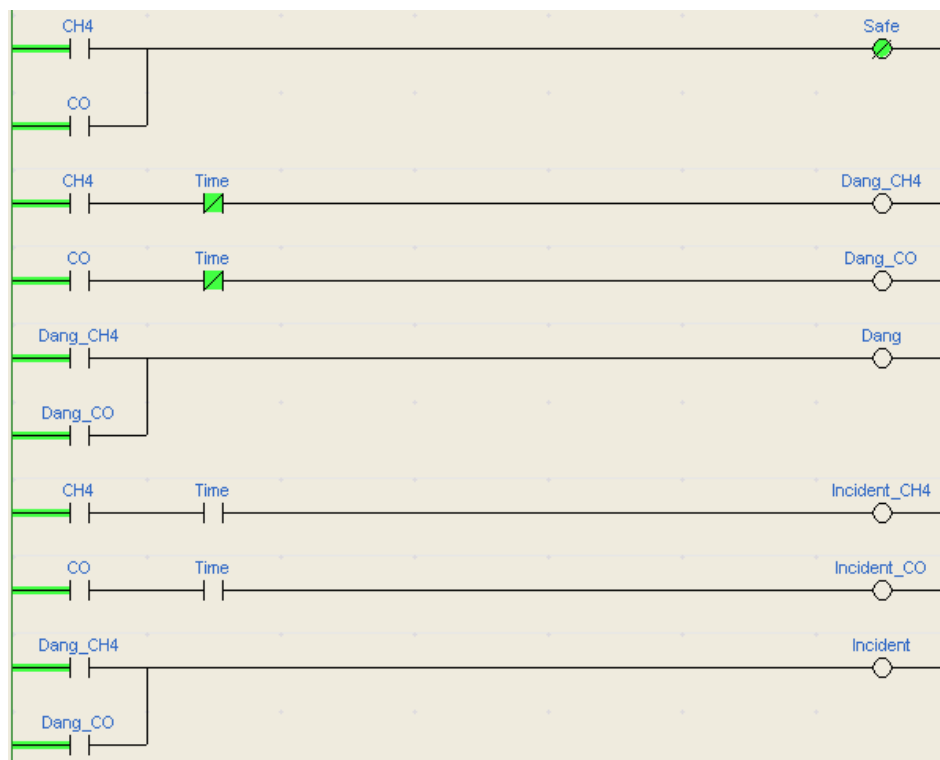


Figure 4. Fragment of the relay-contact circuit.

3.5. Analysis of simulation results

The results of the calculation showed that the concentration of carbon monoxide at the border of the sanitary protection zone and at the border of the nearest territories with normalized indicators of air quality will not exceed the standard hygienic criterion of 5 mg/m³ and range from 0.001 to 0.004 MPC, or from 0.0073 to 0.02 mg/m³. The results of numerical modeling showed the level of pollution from 0.05 mg/m³ to 0.2 mg/m³, which also meets the regulatory standards.

4. Conclusion

When determining the SPZ, it should be taken into account that, in accordance with the methodology [1], for a set of emission sources of individual enterprises, zones of influence are calculated, including circles of a certain radius, conducted around each of the main emission sources (pipes or other sources) of an enterprise, and terrain areas where the total concentration of pollutant from the entire set of sources of this enterprise exceeds 0.05 of the maximum one-time maximum permissible concentration. For operational monitoring of pollution emissions, it is necessary to introduce automation systems.

References

- [1] Bobkova T E 2009 New wording of sanitary regulations and standards 2.2.1/2.1.1.120-03 Control Areas and Sanitary Classification of Enterprises, Erections, and Other Projects *Hygiene and Sanitation* **3** 45-46
- [2] Vaverkov M D, Winkler J and Adamcov D 2019 Municipal solid waste landfill – Vegetation succession in an area transformed by human impact *Ecological Engineering* **129** 109-14
- [3] Hosseini S S, Yaghmaeian K and Yousefi N 2018 Estimation of landfill gas generation in a municipal solid waste disposal site by LandGEM mathematical model *Global Journal of Environmental Science and Management* **4(4)** 493-506
- [4] Sereda T G, Kostarev S N and Elancheva E N 2014 Study safety environmental protection landfills using models anaerobic digesters *Applied Mechanics and Materials* **682** 339–45
- [5] Li A Z, Feng S J and Cao B Y 2019 Numerical simulation of bioreactor landfills subjected to aeration using CFD *Environmental Science and Engineering ICEG 2018* 224-30
- [6] Kostarev S N, Sereda T G and Mikhailova M A 2012 *System Analysis of the Waste Management* (LAP LAMBERT Academic Publishing GmbH & Co)
- [7] Sokolov A K 2017 Conditions for a partial summation of SO₂ and NO₂ hazardous effect in gas emission regulations *Thermal Engineering* **64(12)** 931-4