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N. Rashkevich[1], V. Shershnyov[1], A. Kondratiev[2], O. Shevchenko[1]

[1]*National University of Civil Defence of Ukraine, Ukraine*
[2]*O.M. Beketov National University of Urban Economy in Kharkiv, Ukraine*

DEVELOPMENT OF THE BASIS OF THE METHOD OF CONTROL OF THE EMERGENCY SITUATION RELATED TO FIRE AND EXPLOSION SAFETY OF LANDFILL

It is established that today there is no effective mathematical apparatus that adequately describes the process of preventing a dangerous event and preventing an emergency related to fire and explosion of solid waste disposal facilities close to settlements. The initial and boundary conditions of the existence of the mathematical apparatus are determined, which is the basis for the development of methods of counteracting the emergency. Humidity, the temperature of the landfill, the presence of oxygen at a certain point in time are factors that initiate the danger. The specific weight of the organic component, the value of the density of the array, the height of waste disposal affect the process of counteracting the danger.

Keywords: *solid waste, fire and explosion hazard, mathematical apparatus, initial conditions, boundary conditions.*

The Problem Formulation

In the world, the most common way of dealing with solid waste (MSW) is landfilling in special landfills or dumps, the area of which is growing every year and approaching settlements [1, 2]. An integral part of the operation of these facilities is the combustion processes that take place over the years. However, the problem of fires is especially acute. And given the profitability of obtaining and further use of biogas, which is based on methane gas, and explosions. The combustion of solid waste occurs not only on the surface of landfills but also in the depths of the masses of waste accumulation. As a result of burnout, voids are formed, which are the cause of failures and landslides. According to statistics, media data, at the landfills known cases of dangerous events (NP) are associated with fire and explosion hazards [3, 4], leading to pollution of environmental components due to the additional formation of environmentally hazardous substances (for example, dioxins), the spread of danger over large areas, deaths, injuries, violations of living conditions. Therefore, the task of ensuring fire and explosion safety of solid waste disposal facilities becomes relevant.

Literature Review

The morphological composition of waste is an important characteristic in assessing landfills' fire and explosion hazards [5]. The largest category of waste in the world is food and green waste, which accounts for more than 44% of the total [1, 2].

MSW is a heterogeneous mixture in which almost all chemical elements are present both in pure form and in the form of various compounds. Waste contains components that can burn and support combustion. According to reference data [7], the most common chemical elements in solid waste are carbon and hydrogen. The calorific value of waste is largely determined by these elements.

Studies [8] showed the pyrotechnic characteristics of solid waste samples. In practice, it is impossible to eliminate the combustible component of waste at a landfill or landfill. The most common causes of fires are an increase in the oxygen content of the waste due to the violation of landfill technology (insufficient sealing or insulation layer, the placement of excessive amounts of waste), the excess of biogas collection. The use of large volumes of water during extinguishing can lead to a portion of the oxygen in the thickness of the waste and enhance the processes of aerobic decomposition - the formation of flammable explosive gas - methane. Studies [9] have shown that the increase in temperature in the solid waste mass depends on humidity, morphological composition, activated carbon content, density, heat capacity, thermal conductivity and thermal conductivity of waste. Under certain conditions, the rate of heat release of the oxidation reaction of combustible substances may exceed the rate of heat loss, which leads to a continuous increase in the temperature of the substance and its ignition [5].

Modelling of thermal processes in the waste array shows the patterns of origin and development of combustion processes [10]. The authors [10] proposed to use the methods of mechanics of continuous heterogeneous media.

In [11], a complex thermal analysis of the landfill was carried out using the finite element method, which is implemented in the form of the ANSYS software product. Given the average morphological composition of MSW, the authors obtained integrated thermophysical characteristics of technological layers of MSW, taking into account the different phases of accumulation and weather and climatic conditions of the formation of the upper layer.

The results [12] showed that during the biochemical processes that take place from the surface of the landfill into the massif, first there is an increase in temperature, which reaches its maximum, and then - its decrease. The waste mass reaches a temperature in the range of 20–50 °C, which is a sufficient condition for methanogenesis but is not sufficient for a fire in the absence of additional heat from the ignition source.

Modelling of the temperature distribution in the waste massif under conditions of a different temperature of the combustion source [13] indicates the impossibility of accurate detection on the surface by contact methods of underground fire. The state of development of phytocenoses can be used as an indicator of underground fire, but, unfortunately, low efficiency.

Forecasting and prevention of fires at landfills, as a factor in reducing stability [14], is extremely difficult due to the different specific heat of waste. Until the fire or smoke came to the surface, it is almost impossible to visually detect the ignition source [15].

It is possible to achieve a reduction in the level of fire and explosion hazards at solid waste disposal sites through the controlled extraction of biogas from the waste mass. The interest in biogas as an alternative energy source is growing every year in the world [16]. The main components of biogas are methane (on average up to 60% of the total composition), carbon dioxide, nitrogen impurities, hydrogen sulfide, oxygen, hydrogen and other gases [17]. The qualitative and quantitative composition of biogas is individual for each solid waste disposal site [18] and depends on some factors. In [18], the optimal temperature range of the maximum formation of combustible methane gas in the biogas is given, which is 35–40 °C for mesophilic activity and 50–65 °C for thermophilic activity. However, compliance with the optimal values of the factors of formation of the maximum amount of methane (temperature, humidity) can lead to loss of stability of the waste mass, as a consequence of the danger of landslides of large masses of man-made soil.

The issues of formation of the mathematical apparatus of the method of prevention of cascade-type propagation emergencies associated with landfill landslides at the landfill with liquidation-intensive technological equipment are considered in [19, 20]. The mathematical model of this author's method consists of analytical equations of dependence of the number of dead, injured, people with impaired living conditions on the physical properties of landfill soils, such as humidity, density, temperature, and technological indicators of existing power equipment. The condition for the existence of the proposed model is a set of initial and boundary conditions for the effects of emergencies not to outgrow the object level of hazard distribution, taking into account the maximum amount of methane in the biogas.

Given not only the danger associated with landfill landslides, but the unresolved part of the problem is also the lack of a comprehensive and effective method of counteracting the emergency related to fire and explosion of solid waste disposal sites close to settlements where fire, the explosion can be considered. as initiating the factors of the shift. Thus, there is a need to determine the conditions for the formation of a mathematical apparatus that adequately describes the process of preventing an emergency or preventing an emergency related to fire and explosion of solid waste disposal facilities, which is new for the development of appropriate methods.

The purpose an d objectives of the article

The purpose of the work is to determine the conditions for the formation of the mathematical apparatus of the method of counteracting emergencies associated with fire and explosion hazards of landfills, which are close to the settlements. To achieve this goal it is necessary to determine the initial and ultimate conditions for the existence of the appropriate mathematical apparatus - the basics of methodology.

Discussion of Results

At landfills, there is a possibility of both emergencies and emergencies, which are characterized by the size of the consequences. Methane, as a component of landfill gas (biogas), is a dangerous factor in the occurrence and spread of fire, explosion - emergency or emergency.

Mathematical modelling is the main tool for studying the process of methane generation. To calculate the gas-energy potential of biogas (methane), a large number of mathematical models have been developed: Tabasaran-Rettenberger, B. Weber, LandGEM, AKG. KD Pamfilova, AM Shaimova and others. The most important factors for the study of methane generation are humidity, morphological composition, active carbon content, density, the temperature in the waste mass, storage height, service life of the object.

The optimal approach to obtaining complete and reliable assessment data, methane generation forecast is a combination of mathematical modelling results with field research. However, the use of direct field measurement methods is limited. The limitations are due to their complexity and high cost.

Solid waste at landfills undergoes complex physical, chemical and biological transformations with the release of landfill gas.

The initial volume after unloading of MSW on the landfill map is significantly reduced due to self-sealing. To reduce the volume occupied, the waste is compacted with the help of special heavy equipment (bulldozers, rollers) - the density reaches 1 t / m3. The formed substrate has anomalous geophysical characteristics, anomalous engineering and geological parameters, as well as inhomogeneous filtration properties and poor drainage. The higher the density (microbiological life in such a material slows down), the less gas is formed, and the reduction of waste fractions increases gas formation.

The chemical processes at the landfills are dominated by redox and photochemical reactions, hydrolysis and depolymerization, the formation of sparingly soluble and complex compounds.

Biodegradation occurs under the action of a large number of microorganisms. The main place is occupied by bacteria, which provide the beginning of the process of decomposition of organic matter and a rapid temperature rise. Initially, a group of mesophilic bacteria develops, and after heating the waste medium, a group of thermophilic bacteria begins to actively develop, which can break down more stable organic compounds. It should be borne in mind that several chemicals (such as heavy metals) are toxic and inhibitors of microorganisms.

Aerobic decomposition takes place in the upper layers of the burial massif at a depth of 50–80 cm and is usually quite short, as its duration is limited by the amount of oxygen. This stage is characterized by the formation of carbon dioxide, water, nitrates, nitrites, nitrogen, organic residues and large amounts of heat. As the waste is compacted and isolated by the soil, the aerobic phase of microbiological decomposition tends to become anaerobic-aerobic microorganisms go into an anaerobic state. This is caused by insufficient oxygen supply to the waste layer to meet the conditions of the aerobic process.

Anaerobic decomposition is slower and is accompanied by an order of magnitude less heat release. In the hydrolysis phase under the action of bacteria is the decomposition of easily degradable and hydrolysis of cellulose-containing waste. In the acetogenic (acidic) phase - further decomposition of cellulose with the formation of low molecular weight acids, alcohols. The environment in the body of the landfill becomes very acidic. Acids reduce the hydrogen index, which contributes to the decomposition of easily and moderately decomposable waste. Acids together with moisture release nutrients for methane-forming microorganisms. Then comes the methanogenic phase in which the acids formed in the acetogenic phase decompose, with significant methane formation. Over time, the amount of nutrients decreases and the process of methane formation attenuates. Anaerobic microorganisms receive the energy necessary for life as a result of the decomposition of organic matter. The proportion of the organic component of solid waste (paper, wood, textiles, plant and food residues) determines the number of micronutrients required for methane-forming microorganisms.

Humidity is a necessary factor for the activity of many microorganisms, including methane-forming ones. The solubility of carbon dioxide in water is higher than the solubility of methane, so a high level of solid waste increases the methane content in the gas phase. The actual moisture content in the array is determined by the initial humidity of solid waste, measures to comply with disposal technologies.

Temperature, like humidity, is a determining factor in bacterial activity. Mesophilic groups of methane-forming bacteria actively work at temperatures up to 40 °C, thermophilic - up to 70 °C. The optimal temperature value for the efficient process of methane formation is in the range of 30–40 °C. The level of gas formation decreases significantly when the value of the optimal temperature changes [21].

Taking into account the analysis of factors contributing to the formation of methane in the landfill gas (biogas), the initial conditions of danger are described by expression (1):

$$\begin{cases} w(t) = w_0 \\ T(t) = T_0 \\ O_2(t) = O_{2_0} \end{cases}, \quad (1)$$

The initial conditions for the existence of the mathematical apparatus of the method of counteracting the emergency associated with fire and explosion hazards of landfills, which is close to settlements, is a set of humidity values w, the temperature of the landfill massif T, the presence of sufficient oxygen O_2, which at a certain point in time t initiate the formation of fire-explosive concentration of methane in the array and the spread of danger as a result of exposure.

The boundary conditions for counteracting the danger are described by expression (2):

$$\begin{cases} C_{поч} \le C \le C_{кін} \\ \rho_{поч} \le \rho \le \rho_{кін} \\ h_{поч} \le h \le h_{кін} \end{cases}, \quad (2)$$

The boundary conditions for the existence of the mathematical apparatus of the method of counteracting emergencies associated with fire and explosion hazards of solid waste disposal sites near settlements are a set of interval values of the specific gravity of the organic component. C, density ρ, height of waste disposal h, which affect the process of counteracting the danger.

The figure shows the algorithm of the method of counteracting emergencies associated with fire and explosion hazards of solid waste disposal sites.

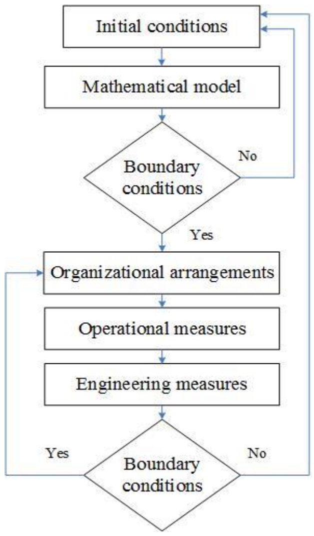

Fig. 1. The algorithm of the method of counteracting emergencies associated with fire and explosion hazards of solid waste disposal sites

Taking into account modern domestic scientific approaches in the field of civil defence of Ukraine [22, 23] and the relevant regulatory framework [25-27], emergencies are a conditional level of the state of emergency, which is achieved by one or more dominant features, in terms of threat, and/or opportunities to counter units of the Civil Service of Ukraine for Emergencies. The number of negative consequences of the emergency should include: the number of victims q_1 and the number of victims q_2, as a consequence of the first priority group; the number of people with impaired living conditions q_3 and the amount of damage caused q_4 – consequences of the second priority group; area of emergency danger q_5 and the costs of emergency response q_6 – consequences of the third priority group.

Given the above, the implementation of emergency response methods related to fire and explosion hazards of solid waste disposal facilities should ensure the absence of damage to both civilians and specialists of the SES of Ukraine. This can be achieved through the development and compliance with effective organizational, operational, informational measures based on the mathematical apparatus - General Equation (3):

$$Q(t) = f(w, \rho, T, O_2, C, h, t), \qquad (3)$$

In case $Q(t) = НП$ – the prevention of emergencies is considered (negative consequences q did not occur), analytical equation (3), describes the relationship between the dependence of explosive methane concentration on humidity, density ρ, temperature T, and the presence of sufficient oxygen O_2, organic component C in the massif of landfill soils (MSW), height h and time t waste decomposition. In case $Q(t) = НС$ – the warning of NC (the area of distribution of danger, costs of elimination of consequences, the size of the caused damage, number of dead, victims, persons with disturbance of living conditions did not reach local level), the analytical equation (3), describes the connection of dependence of the number of dead and injured, as a consequence of the first level of priority.

Conclusions

The solution of the scientific and practical problem in the field of civil safety is obtained in the work: the mathematical apparatus of the method of counteracting the emergency connected with the fire and explosion danger of solid waste disposal facilities close to the settlements are developed. The initial conditions for the existence of the mathematical apparatus of the emergency response method are a set of values of humidity, the temperature of the landfill, the presence of sufficient oxygen, which at some point initiate the formation of flammable methane concentration in the array and the spread of danger.

Boundary conditions are a set of interval values of the specific weight of the organic component, density, height of waste disposal, which affect the process of counteracting the danger.

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Рецензент: д-р техн. наук, професор Р.І. Шевченко, начальник кафедри автоматичних систем безпеки та інформаційних технологій факультету пожежної безпеки, Національний університет цивільного захисту України, Україна.

Автор: РАШКЕВИЧ Ніна Владиславна
PhD, викладач кафедри пожежної профілактики в населених пунктах
Національний університет цивільного захисту України
E-mail – nine291085@gmail.com
ID ORCID: https://orcid.org/0000-0001-5124-6068

Автор: ШЕРШНЬОВ Владислав Олегович
здобувач другого (магістерського) рівня вищої освіти, Національний університет цивільного захисту України
E-mail – sherfb333@gmail.com
ID ORCID: https://orcid.org/0000-0002-3711-7048

Автор: КОНДРАТЬЄВ Андрій Валерійович
доктор технічних наук, професор, завідувач каф. технології будівельного виробництва і будівельних матеріалів
Харківський національний університет міського господарства імені О.М. Бекетова
E-mail – andrii.kondratiev@kname.edu.ua
ID ORCID: https://orcid.org/0000-0002-8101-1961

Автор: ШЕВЧЕНКО Ольга Станіславівна
кандидат технічних наук, провідний фахівець
відділу адміністративної роботи
Національний університет цивільного захисту
України
E-mail – shevchenko605@i.ua

РОЗРОБКА ОСНОВИ МЕТОДИКИ ПРОТИДІЇ НАДЗВИЧАЙНІЙ СИТУАЦІЇ, ПОВ'ЯЗАНОЇ З ПОЖЕЖОВИБУХОНЕБЕЗПЕКОЮ ОБ'ЄКТІВ ЗАХОРОНЕННЯ ТВЕРДИХ ПОБУТОВИХ ВІДХОДІВ

Н.В. Рашкевич[1], В.О. Шершньов[1], А.В. Кондратьєв[2], О.С. Шевченко[1]
[1]Національний університет цивільного захисту України, Україна
[2]Харківський національний університет міського господарства імені О.М. Бекетова, Україна

В роботі проаналізована пожежовибухонебезпека об'єктів захоронення твердих побутових відходів. Метан, як складова звалищного газу (біогазу) є небезпечним фактором виникнення та поширення пожежі, вибуху. Кількісний склад метану залежить від умов функціонування об'єктів захоронення: морфологічного складу відходів, що приймаються, технологій захоронення, температури, вологості масиву відходів. Встановлено, що на сьогоднішній день відсутній дієвий математичний апарат, який адекватно описує процес запобігання небезпечній події та попередження надзвичайної ситуації, пов'язаної з пожежовибухонебезпекою даних об'єктів, що наближені до населених пунктів. Під попередженням розуміється не допустити переростання надзвичайної ситуації з об'єктового на найбільш високий рівень поширення (місцевий), в першу чергу за наслідками першої групи пріоритетності, як то кількість жертв та постраждалих. Визначено початкові та граничні умови існування математичного апарату, що є основою для розробки методики протидії надзвичайній ситуації. Вологість, температура масиву звалищних ґрунтів (твердих побутових відходів), наявність у достатній кількості кисню у певний момент часу ініціюють виникнення небезпеки – утворення пожежовибухонебезпечної концентрації метану в масиві та поширення небезпеки за наслідками впливу. Питома вага органічної складової, значення щільності масиву, висота захоронення відходів впливають на процес протидії небезпеці. Визначено систему рівнянь зв'язку з урахуванням початкових та граничних умов існування математичного апарату, що дозволяє у подальшому розробити керуючий алгоритм методики протидії надзвичайній ситуації, пов'язаної з пожежовибухонебезпекою об'єктів захоронення твердих побутових відходів, що наближені до населених пунктів.

Ключові слова: *тверді побутові відходи, пожежовибухонебезпека, математичний апарат, початкові умови, граничні умови.*