

# Green Technologies: Protective Shield Made of Bentonite Mats for Use in Municipal Waste Landfills

Natalia Martinova<sup>1\*</sup>, Elyor Makhmudov<sup>2</sup>, and Mukhammad Kholikulov<sup>3</sup>

<sup>1</sup>Russian State Agrarian University named K.A. Timirjazev, 127434 Moscow, Russian Federation

<sup>2</sup>Diplomat University, Tashkent, Uzbekistan

<sup>3</sup>“Tashkent Institute of Irrigation and Agricultural Mechanization Engineers” National Research University, 100000 Tashkent, Uzbekistan

**Abstract.** Enhancing urbanization and growing waste volumes pose serious environmental risks, requiring effective solutions to prevent environmental pollution. Currently, the situation with landfills for storing municipal and industrial waste remains tense. Bentonite mats, due to their high absorption capacity, self-healing properties and resistance to physical stress are offered as an environmentally friendly and cost-effective means of protecting soil and water resources from harmful substances. The article considers the possibility of creating a bentonite shield to protect the base of a landfill and determines the required energy consumption. It is proposed to lay out mats by a stacker from standard bays of bentonite mats. The technology of sealing joints with bentonite granules is presented. For these purposes, it is proposed to use fan equipment. This design will protect the base of the landfill, withstanding sanitary, epidemiological and environmental requirements and prevent harmful substances from entering the soil and groundwater, preserving the ecological balance.

**Key words:** Sustainable development; Green technologies; Landfills; Environmental safety.

## 1 Introduction

The growth in the number of large cities is inextricably linked with the increase in the amount of household waste, which sets society the task of developing effective and environmentally friendly methods for their disposal. Despite the efforts of state and local authorities to improve waste collection, recycling and disposal systems, the problem of their safe disposal remains extremely pressing. Inspection organizations constantly record improper collection, untimely removal, illiterate disinfection, almost complete absence of garbage sorting, a low percentage of waste being recycled and, most sadly, the illiterate organization of landfills [1].

Ineffective waste disposal sites lead to serious environmental consequences, including pollution of soil, air and water resources. This contradicts the principles of sustainable development, which require the preservation of natural ecosystems and ensuring the quality

---

\* Corresponding author: [b.ibragimov@tsue.uz](mailto:b.ibragimov@tsue.uz)

of life of future generations. To minimize the negative impact on ecosystems, innovative solutions that comply with the principles of sustainable development are needed.

The territories allocated for the construction of landfills should be equipped with fences, located away from residential areas, and the effluents of the resulting liquid waste should not enter natural watercourses [2]. In fact, there is the opposite situation – the territories allocated for a landfill, over time, increasingly resemble a spontaneous landfill, overflowing in a short period of time. Often, this dump goes beyond the designated boundaries, disrupting the way of life of residents of nearby villages and, often, invading the nature protection zone. Soil, air, surface and groundwater pollution are also common.

Table 1 illustrates the scale of this problem by providing data on large landfills in the Moscow region (Russia). These data demonstrate the scale of the waste management problem in the region and highlight the need to develop and implement more efficient and environmentally friendly waste management methods.

**Table 1.** The main landfills of the Moscow region.

Title	Square, ha	Capacity, thousand tons/year
Khmetevo	79,4	1,100
Dmitrovsky	63,5	1,100
Levoberezhny	26,5	100
Alexensky karjer	20	152
Kuching	59	100
Torbeevo	12,8	162
Kargashino	11,4	100

Sanitary cleaning of settlements and natural areas is a necessary condition for the life support of the population. Unfortunately, among the main methods of waste disposal: recycling, neutralization, warehousing – the last of these is the most widespread [3]. Currently, less than 10% of industrial and household waste is recycled. Growing landfills lead to an increase in environmental and sanitary problems that require immediate solutions. The nature of the area where the landfill is located, or in the immediate vicinity, is experiencing a significant man-made load that the natural forces of self-purification cannot recycle [4].

The way out of this situation would be the use of materials capable of creating a barrier to the penetration of pollutants into the soil and surface waters. Among the materials with the above-mentioned functions, bentonite can be distinguished - a natural clay capable of increasing many times in volume, absorbing liquid and preventing its leakage into deep soil layers, and further into natural water intakes [5]. Another unique advantage of bentonite clay is the ability to self-heal, that is, when the material is damaged, bentonite particles fill the damaged area, restoring the tightness of the coating (Table 2).

**Table 2.** Properties of bentonite granules.

Indicators	Unit of measurement	Bento Standard	Bento Premium
Water output	ml	18	16
Mass fraction of moisture	%	12	12
Granule size	mm	0,5-2	0,5-2
Bulk density	g/sm <sup>3</sup>	1	1

Sanitary cleaning of settlements and natural areas is a necessary condition for the life support of the population. Unfortunately, among the main methods of waste disposal: recycling, neutralization, warehousing – the last of these is the most widespread. Currently, less than 10% of industrial and household waste is recycled. Growing landfills lead to an

increase in environmental and sanitary problems that require immediate solutions [6]. The nature of the area where the landfill is located, or in the immediate vicinity, is experiencing a significant man-made load that the natural forces of self-purification cannot recycle. Thus, bentonite mats can be considered as an inexpensive and reliable coating. Another important feature of bentonite mat is its resistance to frequent freezing and thawing, to hydration and dehydration, and, of course, it should be noted that it is possible to perceive a significant static load without loss of shape. We have to put up with the fact that there is a significant shortage of enterprises engaged in the processing of industrial and household waste. Therefore, in the near future, it is impossible to avoid the allocation of new territories for landfills. Therefore, these structures must meet sanitary-epidemiological, hygienic, environmental requirements, as well as be safe for residents of nearby villages and natural sites.

The research is aimed at developing a technology for creating a protective screen from bentonite mats for use at landfills, as well as assessing the required energy costs for its installation. To achieve this goal, the following tasks were formulated: Analysis of the current state and problems of waste disposal at landfills; Study of the properties of bentonite and the rationale for its use as a protective material; Development of technology for laying bentonite mats and sealing seams; Assessment of energy costs for laying and operating bentonite mats; Conducting experimental studies to test the effectiveness of the protective screen. The implementation of these tasks will allow us to develop a sustainable and environmentally friendly solution to protect the environment from the negative impact of household and industrial waste landfills.

The proposed methods will improve the efficiency of protecting the environment from the harmful effects of waste, preserving the ecological state of territories and water resources near landfills.

## 2 Materials and Methods

Bentonite mats are laid on a prepared base. To form a durable waterproofing coating, it is necessary to connect individual canvases. This is done using bentonite pellets delivered to the joint site by fan equipment.

Determine the air consumption required for the transportation of bentonite granules [7]:

$$Q_g = \frac{k_{3an} \cdot b_c \cdot v_k \cdot \rho_g}{\mu_k \cdot \rho_g} \quad (1)$$

where  $b_c$  is joint width of bentonite mats, m;  $\mu_k$  is the coefficient characterizing the mass concentration of granules transported by the flow;  $\rho_g$  is air density, kg/m<sup>3</sup>;  $\rho_g$  is granule density, kg/m<sup>3</sup>;  $v_k$  is the speed of the machine, m/s;  $k_{3an}$  is stock ratio.

By determining the speed range of the stacker, one can determine the parameters of the fan equipment.

Determine the air flow velocity [8]:

$$v_g = 1,7 \cdot k_{3c} \sqrt{\frac{g \cdot d_z \cdot \rho_g}{\rho_g}} \quad (2)$$

where  $k_{3c}$  is stock ratio of the speed;  $d_z$  is the diameter of the granules, m.

Then, the energy costs of laying the bentonite mat should be determined.

The power required to deliver bentonite granules to the installation site is determined by [9]:

$$N_o = \frac{Q_g \cdot p_u}{10^6 \cdot \eta_{ng} \cdot \eta_g} \quad (3)$$

where  $Q_\theta$  is air consumption, m<sup>3</sup>/s;  $p_H$  is pump pressure, Pa;  $\eta_{ne}$  is efficiency of the fan drive;  $\eta_\theta$  is fan efficiency.

The power spent on laying bentonite mats is calculated by the formula [10]:

$$N_y = \frac{P_\theta \cdot f_\theta \cdot (0,5 \cdot D - h) \cdot \omega \cdot k_{san}}{1000 \cdot \eta_y} \quad (4)$$

where  $h$  is deformation of the bay, m;  $k_{san}$  is stock ratio;  $\eta_y$  is the efficiency of the stacker;  $D$  is the diameter of the bentonite mat bay, m;  $P_\theta$  is vertical reaction of the soil to the bay, N;  $\omega$  is angular velocity of the bay, s<sup>-1</sup>;  $f_\theta$  is the coefficient of friction of the mat on the ground.

We will determine the vertical reaction of the base to the bentonite mat stacker bay [11]:

$$R_\theta = 4,84 \cdot 10^{-2} \cdot \frac{E \cdot J}{0,0625(D-d)^4} \cdot \sqrt{\frac{0,5 \cdot (D-d) \cdot E \cdot J}{q_{cp}}} \quad (5)$$

where  $E$  is modulus of elasticity, Pa;  $d$  is diameter of the bay shaft, m;  $q_{cp}$  is distributed inertia force, Nm<sup>-1</sup>;  $J$  is moment of inertia, kg·m<sup>2</sup>.

The distributed force of inertia is determined by the formula [12]:

$$q_{cp} = 2 \cdot m_\theta \cdot \omega^2 \quad (6)$$

where  $m_\theta$  is the mass of the bentonite bay, kg.

The moment of inertia is determined by the formula [13]:

$$J = \frac{\pi \cdot D^4}{32} \cdot \left(1 - \frac{d^4}{D^4}\right) \quad (7)$$

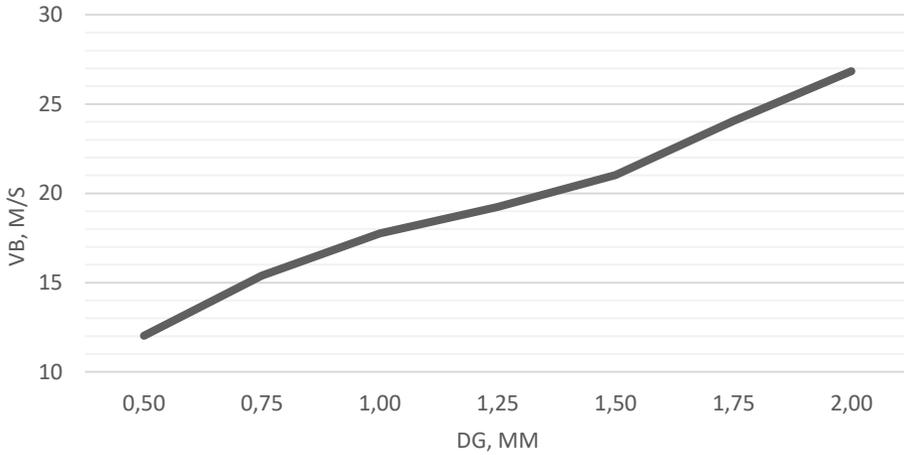
The total energy costs will be [14]:

$$N_{po} = N_y + N_\theta \quad (8)$$

### 3 Results and Discussion

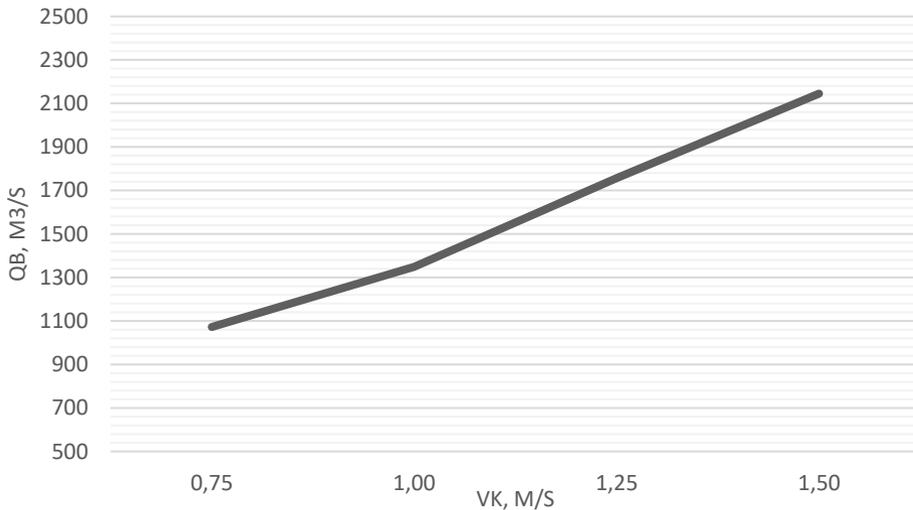
Despite the small size of bentonite granules, the required air flow rate for their delivery is high. In this regard, there are some difficulties with the distribution of bentonite granules over the joint surface (Fig. 1).

Fig. 1 illustrates the dependence of the required air flow on the size of bentonite granules during their transportation to seal the joints of bentonite mats. The graph shows data showing that as granule size decreases, the required air flow increases. This is due to the fact that smaller granules require higher air flow rates to effectively transport them and distribute them evenly over the joint surface. The figure also shows a non-linear relationship, showing that at certain granule sizes the increase in air flow becomes more significant. This schedule is important for optimizing the installation process of bentonite mats, as it allows one to select appropriate air flow parameters, minimizing energy costs and ensuring effective sealing of joints.



**Fig. 1.** The required air flow rate depending on the size of the granules.

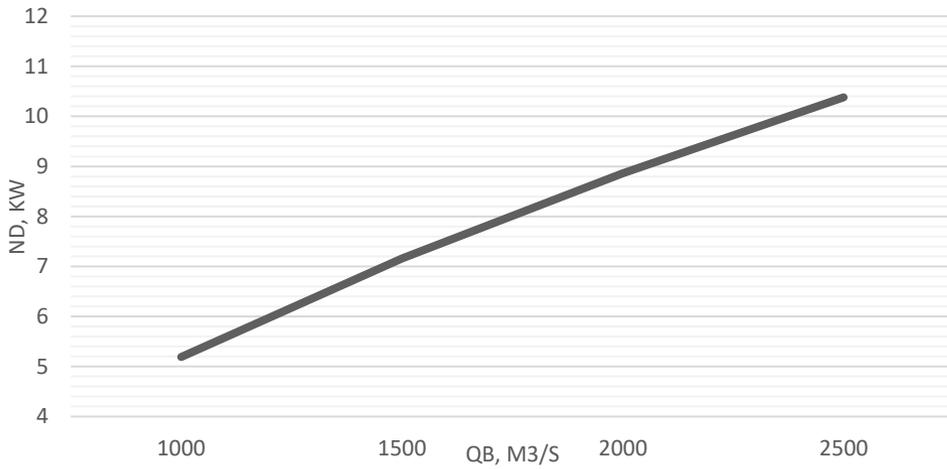
The air consumption will also be significant, which will require a compressor unit (Fig. 2). The graph shows a direct relationship, according to which an increase in the speed of the paver leads to an increase in the required air flow. This dependence is explained by the fact that at higher laying speeds, more intense air flow is required to maintain a stable and uniform distribution of granules over the joint surface. Thus, the graph helps determine the optimal operating speed of the paver, which will allow achieving effective sealing of joints with minimal energy consumption. These results are important for selecting equipment parameters and planning the process of laying bentonite mats, which ultimately helps to increase the reliability and durability of the protective screen at waste sites.



**Fig. 2.** Dependence of the required air flow rate on the speed of the stacker.

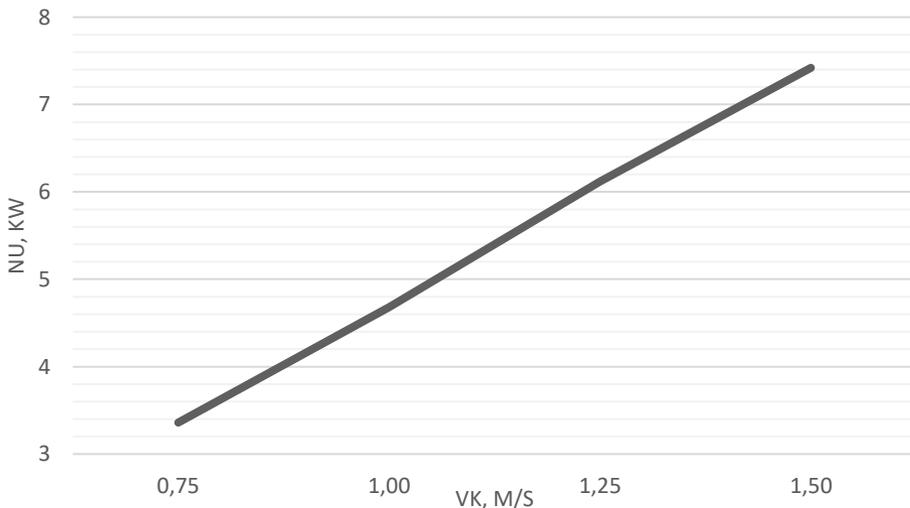
Having determined the required air consumption and selected the fan equipment, we will determine the range of energy consumption for transporting bentonite granules to the junction (Fig. 3). The graph shows that energy consumption increases with decreasing granule size. This dependence is due to the fact that smaller granules require more energy to move them and distribute them evenly over the joining surfaces, which is associated with the need to

maintain a higher air flow speed. This data are key to optimizing the installation process of bentonite mats, as it allows selecting a granule size that will strike a balance between sealing quality and minimal energy costs.



**Fig. 3.** Energy consumption for transportation of bentonite granules to the junction.

To determine the optimal values of the power spent on the layout of bentonite mats, consider the speed range of the stacker (Fig. 4). The graph shows a direct relationship showing that as the paver speed increases, the energy costs for laying the mats also increase. This dependence is explained by the fact that at a higher speed of the paver, more energy is required to overcome the resistance that occurs when the mats come into contact with the ground surface, as well as to ensure a uniform and tight fit of the mats to the base. Fig. 4 clearly shows that the trade-off between process performance and energy costs must be taken into account when choosing paver speed. Increasing the laying speed, although it speeds up the process, leads to an increase in energy consumption, which can affect the overall economic efficiency of the technology.



**Fig. 4.** Energy consumption for the layout of bentonite mats.

Studies have shown that bentonite mats are a reliable waterproofing material that can be effectively used to create a protective shield in order to prevent contamination of soil and

groundwater with industrial and household waste. Unfortunately, to date, work on large-scale waste sorting has not been established and there are catastrophically not enough plants for their processing. Therefore, the only way out of this situation is to form a set of protective measures to prevent harmful substances from entering the soil and groundwater. The proposed technology will help solve this problem.

## 4 Conclusion

In the course of the study, a technology for using bentonite mats as a protective screen for household and industrial waste landfills was developed and evaluated. We have proved that the use of bentonite mats can effectively prevent the penetration of pollutants into the soil and surface waters, which is consistent with the principles of sustainable development and environmental protection. Bentonite has unique absorption and self-healing properties, which makes it an ideal material for creating durable and reliable protective screens. The data confirmed that the proposed technology for laying bentonite mats and sealing joints ensures a high degree of environmental safety of landfills. The implementation of this technology in practice will significantly improve the environmental situation near landfills, helping to preserve natural ecosystems and ensure sustainable development.

## References

1. N.S. Sevrugina, A.S. Apatenko, Performance Monitoring of technical Systems of water Management Facilities. *Bulletin of Land Reclamation Science* **1** (2020) 40-46
2. L.V. Kireycheva, V.M. Yanshin, Theoretical Approaches to Justification of integrated Reclamation Systems. *Melioration and Water Management* **5** (2019) 31-35
3. B.M. Kizyaev, N.B. Martynova, Implementation of scientific Projects in the Sphere of Development of the Reclamation Complex of Russia. *Environmental Management* **5** (2015) 13-17
4. E.V. Zhalnin, About the Fundamental of agricultural Mechanics. *The Herald of the Moscow State Agricultural Engineering University named after V.P. Goryachkin* **82**, 6 (2017) 10-14
5. A.Yu. Korneev, N.B. Martynova, Plain working Body for Construction of Reclamation ducts of semi-elliptic Profile in the drainage Area. *The Herald of the Moscow State Agricultural Engineering University named after V.P. Goryachkin* **78**, 2 (2017) 26-29
6. B.M. Kizyaev, N.B. Martynova, System of Machines for integrated Mechanization of reclamation Works. *Creation History and Prospects. Irrigation and Reclamation* **13**, 3 (2018) 62-65
7. L.V. Kireycheva, L.A. Lentyaeva, Influence of agricultural Production on Pollution of water Bodies. *Environmental Management* **5** (2020) 18-26
8. H.A. Abdulmashidov, A.S. Matveyev, Integrated Design and strength Calculations of natural equipment Machines in INVENTOR Pro system. *The Herald of the Moscow State Agricultural Engineering University named after V.P. Goryachkin* **72**, 2 (2016) 40-46
9. V.V. Melikhov, A.A. Novikov, L.N. Medvedeva, O.P. Komarova, Green Technologies: The Basis for Integration and Clustering of Subjects at the regional Level of Economy. *Contributions to Economics* (2017) 365-382

10. H.A. Abdulmazhidov, Design Features and Calculation of Productivity of the channel Cleaner with a Bucket on a rigid. Guide. The Herald of the Moscow State Agricultural Engineering University named after V.P. Goryachkin **78**, 2 (2017) 21-25
11. N.S. Sevrugina, A.S. Apatenko, E.V. Voytovich, Risks of the Ecosystem in the Functioning of water management Complexes. Environmental Management **2** (2020) 115-122
12. G.I. Bondareva, Problems of Forming a national System of Standardization in Reclamation. Rural Mashine Operator **10** (2020) 22-23
13. V.A. Shevchenko, G.I. Bondareva, A.M. Solovjov, L.V. Kudrjavitzeva, Assessment of the Acid State of low-productive irrigated Lands Depending on the fertilizer System and the Preceding crops. Engineering for Rural Development (2020) 1065-1068
14. N.K. Telovov, H.A. Abdulmazhidov, Experimental Studies of the physical Model of the working Body of a two-level deep Driller. The Herald of the Moscow State Agricultural Engineering University named after V.P. Goryachkin **91**, 3 (2019) 22-27