



Research Journal of Pharmaceutical, Biological and Chemical Sciences

Validation of Processing Methods for Peat Raw Dehumidification with Excavating Digging.

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The results of theoretical and experimental studies are presented that focus on validating the manufacturing parameters of the peat raw production under conditions of applying a developed manufacturing scheme of the modular peat enterprise operation. The conducted studies revealed the dependences of the gravitational dewatering efficiency factors on the initial conditions of dehydration caused by the values of the pile height and moisture content. An example of the evaporation rate calculation at the convective and radiative-convective heat supply is given for the average data of summer months. The calculation results indicated an increase in the role of evaporation in the gravitational dewatering of peat raw under the favorable weather conditions.

Keywords: peat digging, drying rate, manufacturing parameters.

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INTRODUCTION

In the current conditions of economic management, where the energy component takes up to one third of the total volume of the Russian freight traffic, the question of enhancing energy security becomes more and more acute, one of the ways to ensure which is the intensive involvement of the local fuel and energy resources, and in particular of peat fuel, by the power generating enterprises.

One of the main obstacles to an active use of the local peat fuel as the primary one is the low reliability of the existing manufacturing schemes of peat digging under conditions of operation of relatively small peat enterprises.

During the transition to the exceptionally shop-floor conditions of peat fuel production, it is possible to significantly simplify the technology of raw digging having reduced the need for field preparation for peat digging and drying under the field conditions, warehousing, storing, and transporting products, and to significantly reduce the dependence of digging cycle on the weather conditions, fire hazards, etc. In some cases, such technologies may be reduced to the small-scale year-round peat digging using an excavation method or the milled peat of increased humidity digging, which enhances significantly the reliability of the peat fuel production and its supplies to the consumer, but in turn requires a considerable amount of energy for the process of removing large amounts of water from the raw material at the shop floor stage of the agglomerated fuel production. When implementing the manufacturing scheme of excavating digging, all tasks of the field stage of production can be accomplished on a small site of the deposit with a minimum set of technical equipment for general purposes (a marsh excavator, a water boggy bulldozer, machine-tractor aggregates, and a front-end loader) and its arrangement is possible with involvement of minimum investments, which is extremely attractive for small companies. The manufacturing scheme of production under study is disclosed in the Patent "Modular Manufacturing Complex of Peat Digging and Agglomerated Fuel Production" [6, 7].

One of the ways to improve the energy efficiency of the agglomerated peat fuel production at the peat enterprises with a small-scale year-round digging is the combination of processes of the field and shop floor moisture removal and the operational management of production depending on the changing environmental conditions.

The choice of rational parameters when performing the technological operations of the field enrichment of peat raw of high humidity should be determined based on the provision of maximum drying rate in the given meteorological conditions as well as through the optimization of energy costs for the dewatering of peat raw. Solving of this problem requires a comprehensive study of the process of dewatering the waterlogged peat raw with 84 to 90% of moisture under the influence of gravity and capillary-osmotic forces as well as due to evaporation.

Based on the previous studies, it is determined that the targeted range of humidity for the peat raw supplied to a shop floor module of the peat fuel production through extrusion method is the humidity of 60% to 70% [6, 9, 10]. In some cases, during the diversification of production, this range can be extended up to 50-70%. Thus, the task of the field stage of peat enrichment in quarrying is to reduce humidity from 84-90% to 50-70%.

METHODOLOGY

In studying the moisture conductivity of waterlogged peat deposits of disturbed structure under the influence of gravity P_g and capillary-osmotic P_k forces, the conditions are created when $P_k = P_g$, at which the rate i_g of moisture flow tends to zero ($i_g \rightarrow 0$), and the height h of peat layer tends to the limit (minimum value) $H_{cr} = const$ with a corresponding value of the effective radius of pores r . After reaching the critical height through peat pile, the dewatering stops, and for the further removal of moisture, the mechanical raw pressing or peat drying operations (field or factory drying) are required.

The conducted studies revealed the dependences of the gravitational dewatering efficiency factors on the initial conditions of dehydration caused by the values of the pile height and moisture content.

DISCUSSION AND RESULTS

Given the fact that the experimental value of the critical height of pile H_{crE} is associated with the theoretical value H_{crT} through the coefficient β taking into account peculiarities of the real structure and indirectly reflecting resistance to the transfer of moisture [1, 2, 3, 4, 5, 6, 7, 8], $H_{crE} = H_{crT} \cdot \beta$, were obtained the following expressions for calculating the efficiency factors of gravitational dewatering:

$$F_{ef}^/ = 1 - \frac{\beta \cdot 2\sigma \cos\Theta}{h_i \cdot r\rho_f g}, \tag{1}$$

$$F_{efw}^/ = 1 - W_{cr} / W_i, \tag{2}$$

where σ is the surface tension factor, H/m ; r is the pore radius, m ; Θ is the angle of wetting solid body with fluid, *degrees*; g is the acceleration of gravity, m/s^2 ; ρ_f is the bound fluid density, which can $\rho_f = (0.81 \div 1.32) \cdot 10^3 \text{ kg/m}^3$, respectively, at $T = 273 \div 311 \text{ K}$; W_{cr} , W_i is the moisture content at filtration balance and the initial moisture content, respectively, $kg(v)/kg(s)$.

The considered filtration balance ($P_k = P_g, i_g = 0$) will be disturbed due to evaporation of moisture from the surface of peat raw pile, i.e. at

$$P_k \leq P_g, i = (i_g + i_u) > 0, \tag{3}$$

where i_u is the moisture evaporation rate at $h_i \geq H_{cr}$. In this case, the additional moisture loss will be carried out due to its evaporation from the surface of the formed films, menisci of large and narrow pores, and due to capillary moisture feeding into the evaporation zone. Thus, when determining the total flow of moisture, a peat raw pile will generate a gravitational flow i_g and evaporation i_u .

In case of radiative-convective heat supply, it is required to introduce the radiant component of the heat flux q_r , which can be expressed in terms of radiation balance B allowing for losses Δ of heat through the pile base, especially for the samples small in height,

$$q_r = \frac{B(100 - \Delta)}{100}. \tag{4}$$

Thus,

$$i_u = \frac{q_r + \alpha_q(t_c - t_n)}{R_n}, \tag{5}$$

which at small energy losses ($\Delta \rightarrow 0$) will be

$$i_u = \frac{B + \alpha_q(t_c - t_n)}{R_n} = \frac{B + q_k}{R_n} = \frac{q_0}{R_n}, \tag{6}$$

where $q_0 = B + q_k$ is the total heat flux, W/m^2 ; R_n is the specific heat of evaporation, J/kg ; α_q is the coefficient of the external heat exchange, W/m^2K ; t_c, t_n is the ambient temperature and the temperature of surface, respectively, K .

The conducted theoretical studies allowed to obtain an expression for the determination of the total flow of moisture from the peat raw pile:

$$i = i_g + i_u = -k_v \left(\frac{2\sigma \cos\Theta}{r_i h_i} - \rho_f g \right) + \frac{q_r + \alpha_q (t_c - t_n)}{R_n} \tag{7}$$

For real environments, taking into account the efficiency of moisture conductivity (effective coefficient of moisture transfer), this equation (7) takes the form:

$$i_u = -F'_{ef} \left(\frac{P_k - P_g}{h_i} \right) + \frac{B + \alpha_q (t_c - t_n)}{R_n} \tag{8}$$

That is, at $P_k < P_g, h_i > H_{cr}$ the value i_u is reciprocal of the pile height h_i and pore radius r , proportional to the heat flux q_0 and pressure drops $\Delta P = (P_g - P_k)$.

For another case, when $h_i \leq H_{cr}$ the gravitational flow is excluded ($i_g = 0$), and the gradient of moisture content changes only due to the moisture evaporation. Therefore, the substance mass preserving condition makes it possible to determine that the amount of fluid supplied to the evaporation zone equals the amount of evaporated moisture.

To assess the possibility of applying the obtained theoretical expressions in the practice of calculating manufacturing parameters of the process of field enrichment of the peat raw, a series of experimental studies was carried out using the natural peat samples at the convective and radiative-convective heat supply.

The comparison of gravitational dewatering i_g with evaporation i_u of moisture from the pile surface was carried out based on the functional dependence $i_g = f(\tau)$ at various values of the peat pile height h_p .

Table 1: Comparison of gravitational dewatering with evaporation of moisture from the peat pile surface at various heat supply (C and RC modes, $i_g = i_u$)

Pile height, $h_p \cdot 10^3, m$	Time τ, h						Balanced time τ_p, h	
	0.5	4.5	21	49	109.5	225.5	C mode	RC mode
	Dewatering rate $i_g, kg/(m^2h)$							
100	12.99	0.76	0.12	0.06	0.003	0	18.0	8.0
150	18.39	1.57	0.25	0.05	0.002	0	20.0	15.5
200	19.51	2.69	0.35	0.15	0.003	0	37.0	15.0
300	26.14	4.48	0.90	0.18	-	0.005	45.0	30.0
400	31.35	5.58	1.46	0.44	0.069	0.015	60.0	43.0

Note:

- We used a highbog scheuchzerite-sphagnum peat $R_p = (22...25)\%$. The studied were conducted under ambient conditions (convective heat supply) at $t_c \approx 21.8^\circ C, t_n \approx 15.2^\circ C, \varphi = 47\%, q_r = 0$, the speed of air flow $v \leq 2$ m/s, $W_i = 16.432$ kg/kg. In assessing the movement of moisture in the

conditions of radiant-convective heat supply, we took the value of $q_r = 0.38 \text{ kW/m}^2$, $t_c \approx 21.8 \text{ }^\circ\text{C}$, $t_n \approx 15.2 \text{ }^\circ\text{C}$, $\Delta t = 6.6 \text{ }^\circ\text{C}$, $v \leq 2 \text{ m/s}$.

2. C and RC are the convective and radiative-convective heat supply modes, respectively.
3. The τ_p values are obtained by extrapolating the intersection graphs $i_g = f(\tau)$ and $i_u = f(\tau)$ along the axis τ .

In calculating the rate of evaporation in convective and radiative-convective heat supply for the average data of summer months, we obtained the values i_u differing by more than 2.5 times, indicating the growing role of evaporation in the gravitational dewatering of peat raw under favorable weather conditions.

A detailed analysis of Table 1 confirms the need to take account of evaporation from the surface of pile the sooner the lower its height h_p is and the higher the heat flux at $h_i > H_{cr}$ is. At $\tau = \tau_p$, the value of evaporation rate i_u equals the rate of gravitational dewatering i_g , but at very low values i_u , the contribution of which into the overall flow of moisture at various h_p is insignificant, in the period of $\tau < \tau_p$ it can be ignored. At the low rates of dewatering, the contribution i_u grows and it should be obligatory taken into account at $\tau > \tau_p$, i.e. when $h_p \rightarrow H_{cr}$. At $h_p = H_{cr}$, the role of i_g is excluded from the total balance of moisture $i = i_g + i_u$ ($i_g = 0$, $P_k = P_g$) and $i = i_u$.

CONCLUSION

Thus, the gravitational dewatering of peat pile is the determining up to $h_i > H_{cr}$ as compared to the evaporation of moisture from the pile surface increasing as the temperature and radiation balance ($q_r = B$) grow, and the relative air humidity φ_c decreases. We believe that the boundary of taking into account the evaporation is the time of "balance" τ_p at $i_g = i_u$, that is, when the evaporation accounts for 50% of moisture flow. In view of the data obtained, we consider it possible to recommend the developed approaches in selecting rational parameters of peat raw pile of disturbed structure in the operations of prior dewatering as well as for assessing the optimal duration of the pile gravitational dewatering period under changing (in a wide range) weather conditions of the extended season of peat digging.

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