STUDY OF DEHYDRATION OF ORGANIC SAPROPEL BY COMPRESSION METHOD

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Abstract. In the Polissya part of the Volyn region of Ukraine there are mainly sod-podzolic soils, which are characterized by low natural fertility, so the application of fertilizers, especially organic ones, is a determining factor in obtaining high yields. For this region, a great reserve for increasing soil fertility is the use of sapropels as organic fertilizers. The potential of sapropels as an alternative source of organic matter for the preservation and reproduction of soil fertility in Ukraine as a whole is 140 million tons when converted to 60% moisture. In its natural state, sapropel is a colloidal system with a moisture content of 92...98%. Therefore, the main and most energy-intensive operation of its processing is dehydration. Studies have shown that free (capillary) moisture is the least energetically bound, it is held in the material mechanically due to its porous structure and can be extracted by compression. Known studies of this process are based on discrete measurements. Therefore, an automated system for measuring the amount of water released from sapropel in the process of its compression in a closed volume with information processing using computer technology was developed. To build an automated measuring device we used a strain gauge (SBR-1); analog to digital converter (NX 711); water flow sensor (YF-S401). As a controller Arduino UNO ATmega 328P-PU was used, and for signal processing on a computer – LabVIEW environment. To obtain a mathematical model of the studied process in the form of a regression equation, a symmetric non-compositional plan of the Box-Behnkin experiment of the second order was used. According to the obtained regression equation, the response surface was constructed. Based on the analysis of the response surface, it was found that it is possible to reduce the water content in the studied samples of organic sapropel from 94% to a minimum value of 72-74% at a sample pressure of 80-100 kPa and a holding time under load of 22-26 s.

Keywords: dehydration, organic sapropel, measuring device, regression equation.

Introduction

The intensification of agricultural production in Ukraine has led to irreversible soil degradation. These processes are particularly noticeable on soils with a light texture. For example, in the Polissya region of Volyn Oblast, Ukraine, there are predominantly sod-podzolic soils characterized by low natural fertility. Therefore, farmers ensure high yields by applying increased doses of mineral fertilizers. However, only organic fertilizers can help stabilize natural fertility. At the same time, the region is home to a large number of freshwater lakes with 65 million tons of sapropel deposits. In general, Ukraine's projected sapropel reserves are 140 million tons when converted to 60% moisture content [1]. The results of research by many scientists indicate the multifaceted and systematic positive impact of sapropel on soil fertility [2-5].

Peculiarities of sapropel deposit formation are caused by their high moisture content. Thus, organic sapropel deposits of lakes in the Volyn region have a natural moisture content of 92-98% [6]. Therefore, the direct use of extracted sapropel as an organic fertilizer is limited. To obtain a product suitable for transportation over medium and long distances, it is necessary to dehydrate natural deposits. This operation is associated with significant energy costs.

Well-known studies have shown that the extracted sapropel contains a significant amount of free (capillary) moisture. This type of moisture has the lowest energy bond and is retained in the material mechanically due to its porous structure and can be extracted by compression [7]. The known studies of sapropel dehydration by compression in a closed chamber are based on discrete measurements of the volume of liquid released [6]. The results of these studies indicate that with an increase in the compressive load above 100 kPa, the intensity of liquid release decreases sharply.

There is also a wide range of experimental studies of moisture extraction by mechanical means from materials with high moisture content. Thus, the study of dehydration of mineral sludge (kaolin) in a laboratory filtration and compression chamber is described in [8]. The installation described in the paper provides continuous recording of the amount of liquid released. The amount of moisture reabsorption after removing the compressive load from the samples was studied in [9]. A suspension based on coal dust was used as a test material. The effect of an electric field of different voltages on the intensity of moisture removal from sludge from sewage treatment plants was studied in [10]. The results of the study

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indicate that the effect of an electric field in combination with pressure can increase the solids content by up to 45%.

In the last 10 years, pipes made of geotextile materials have become widespread for dewatering various sediments, including sapropel. A wide range of studies have been conducted to find ways to intensify the release of liquid through geotextile materials [11-14]. They are aimed at selecting the optimal composition of the geotextile material of the pipe [11], studying the impact of using an open and closed pipe [12], establishing the adequacy of theoretical models of liquid filtration through the pipe walls [13], the possibility of dehydrating liquid animal manure [14], etc.

The analyzed studies reveal many issues of the sapropel dehydration process, but there is a need for a more complete study of sapropel dehydration from lakes in the Volyn region within the pressure range that ensures the highest process efficiency. In view of the above, an installation for automated study of the dehydration process by the compression method was developed, and experiments were carried out with samples of organic sapropel extracted from Lake Zyatske in the Volyn region.

Materials and methods

The research was based on a compression and filtration unit equipped with a lever-sector press with a 1:10 leverage ratio. To automate the study, the installation was modernized by installing sensors that automatically record the amount of the applied load and the amount of liquid released from the sample (Fig. 1-2).

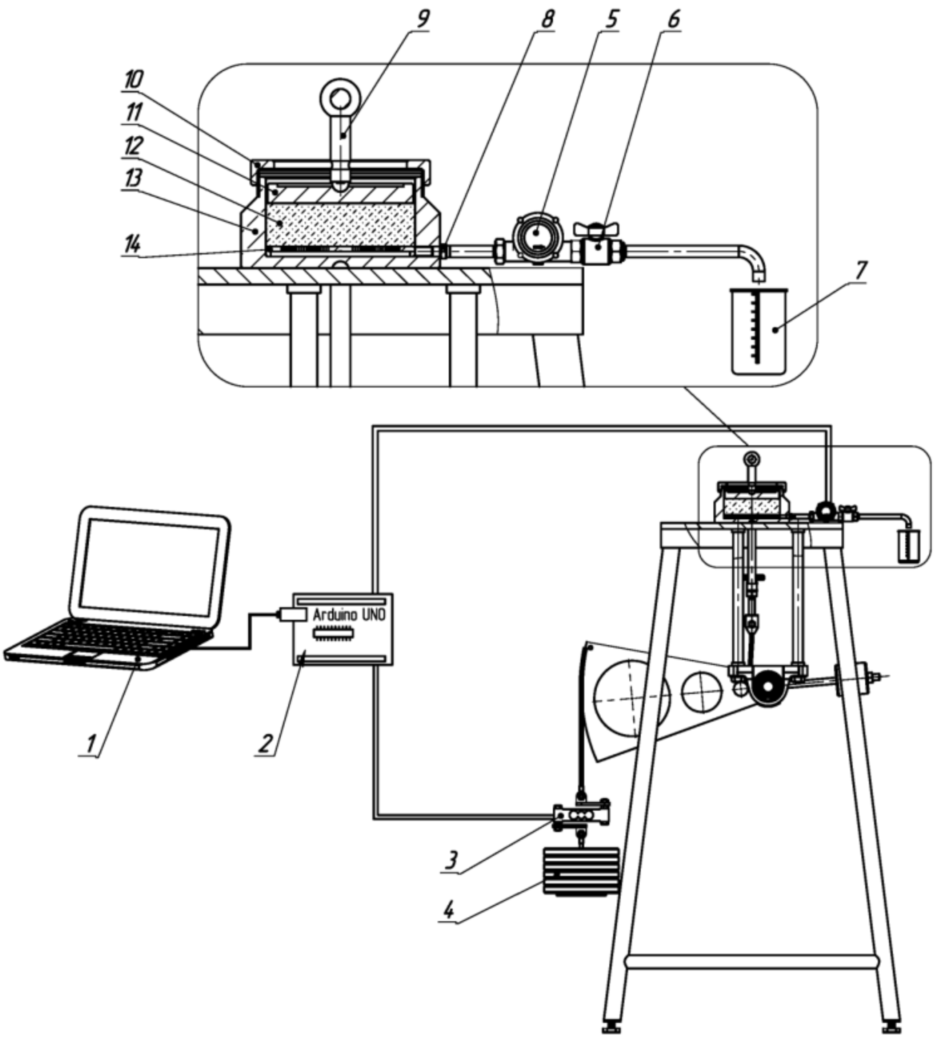

Fig. 1. **Scheme of the experimental setup**: 1 – laptop; 2 – Arduino controller; 3 – strain gauge SBR-1; 4 – load; 5 – flow meter YF-S401; 6 – tap; 7 – measuring cup; 8 – fluid outlet fitting; 9 – loading frame; 10 – ring; 11 – stamp; 12 – sample sapropel; 13 – housing; 14 – filter ring

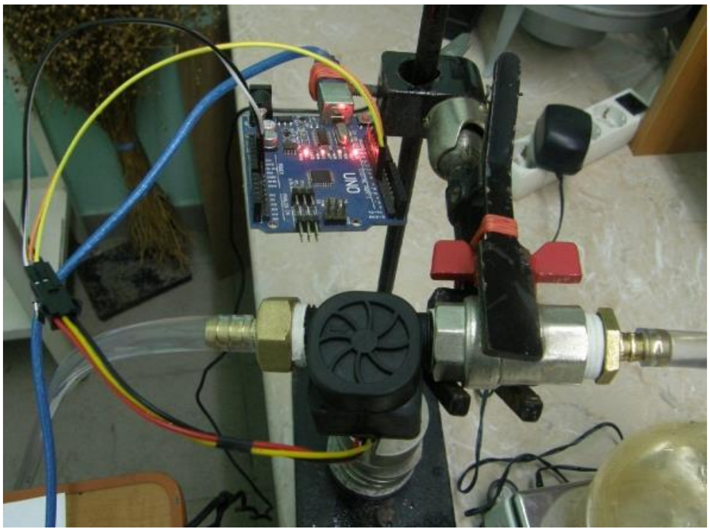

Fig. 2. **Liquid flow controller and sensor**

The YF-S401 flowmeter and the SBR-1 load cell communicate with the computer via the Arduino UNO ATmega328P-PU controller. An analog-to-digital converter NX711 was also used to operate the SBR-1 load cell. The LabVIEW environment was used as software for receiving and processing signals from the controller. The signals from the sensors were recorded by the controller and then transferred to a PC, where they were processed by the program and displayed in the form of graphs (Fig. 3).

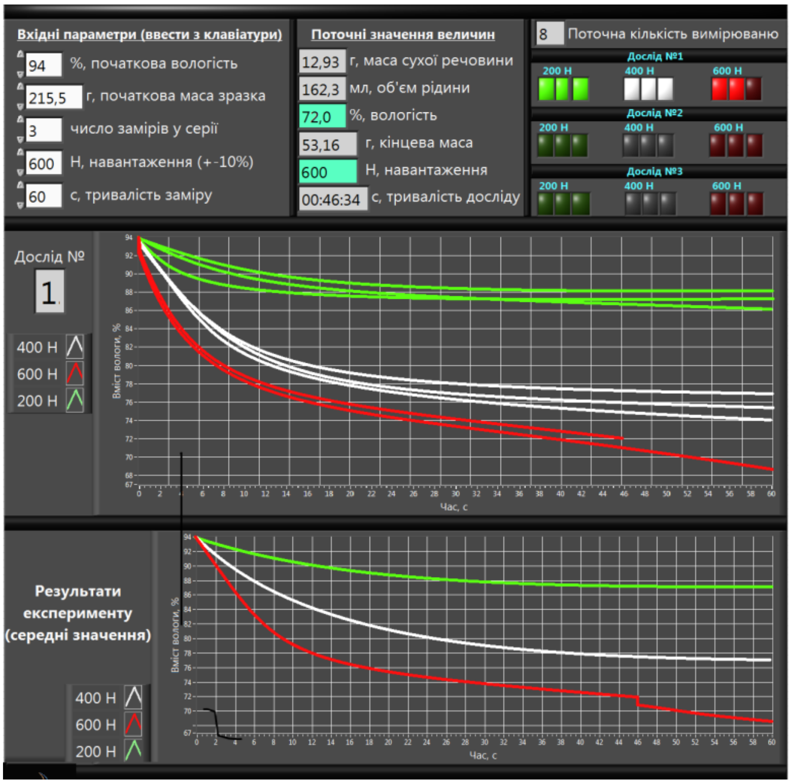

Fig. 3. **Dialog box of the data processing program**

In the housing 13, the test sample of sapropel of natural moisture was placed wrapped in filter paper. The sample weight was within 200-240 g and was previously determined to the nearest 0.01 g. The material loaded with the sample was pressed from above by a stamp 11 and a compressive load was applied through the frame 9. The liquid released from the sample enters the chamber of the flowmeter 5 through the nozzle 8 and then is drained into the measuring cup through the nozzles. Sapropel extracted with a pneumatic device described in [15] was used in the experiments. Therefore, the studied material was aligned according to its composition. The initial moisture content of the sapropel samples under study was 94%.

In order to obtain a mathematical model of the sapropel dehydration process in the form of a regression equation, a mathematical planning method was used for a two-factor experiment based on a symmetric non-composite Box-Benkin plan of the second order. The significance of the coefficients of the regression equation was checked by the Student's criterion, and the adequacy was checked by the Fisher's criterion.

The described methods are universal and can be used to study other types of sapropel.

Results and discussion

Based on the results of the experiments, we obtained graphs of changes in the moisture content of organic sapropel (Fig. 4). The analysis of graphical dependencies shows that in the time interval from 0 to 10 seconds under all studied loads the most intense liquid release occurs. After 20-30 seconds and until the end of the experiment the moisture release reaches its minimum values.

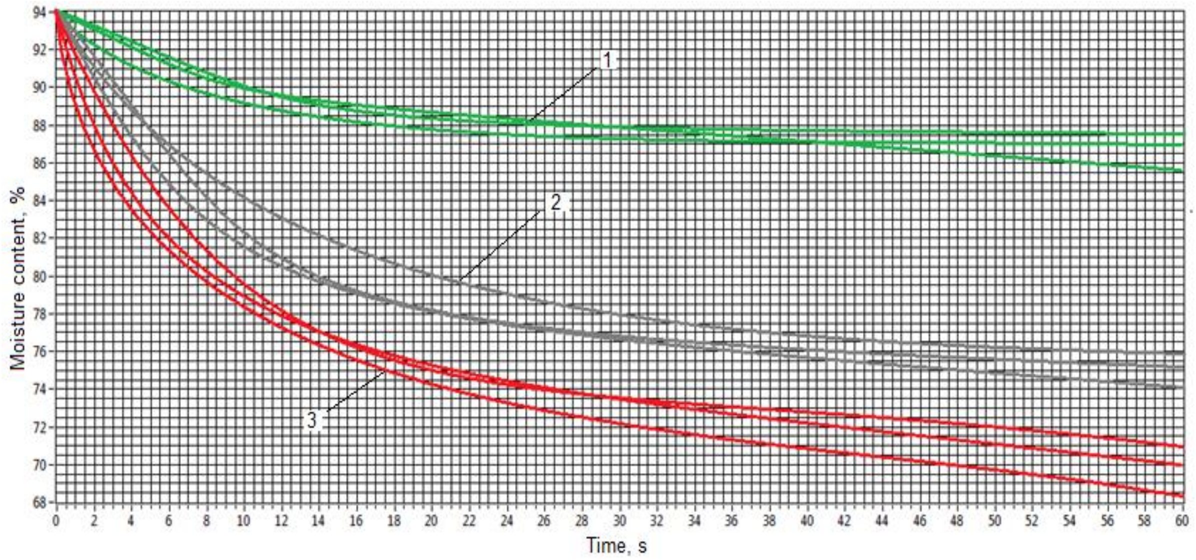

Fig. 4. **Graphical dependence of the moisture content of organic sapropel samples on the time of its compression under applied pressure:** 1 – 33.3 kPa; 2 – 66.7 kPa; 3 – 100.0 kPa

The nature of the obtained graphs coincides with the results obtained in experiments with mineral sludges reported in [8]. It is noted that at the first stage of compression, there is an instantaneous decrease in the volume of pores filled with liquid, and hence its intensive release outside the sample. At the second stage, the compression of the material is slowed down by the influence of internal viscous friction forces. From the point of view of practical use in mechanical dehydration devices the first stage is the most appropriate, so it was decided to obtain a model of this process in the form of a regression equation.

The use of a second-order plan made it possible to obtain a regression equation that describes the process of moisture release from the tested samples in the time range of 0-30 s, which corresponds to the stage of the most intense liquid release from the samples. After converting the factors from coded values to natural values, we obtained equation (1), on the basis of which the response surface was constructed (Fig. 5)

$$W = 102.751 - 0.243384 \cdot P - 0.673133 \cdot t + 0.001488 \cdot P^2 + 0.021791 \cdot t^2 - 0.007335 \cdot P \cdot t, \quad (1)$$

where W – moisture content, %;
P – pressure, kPa;
t – time, s.

The analysis of relation (1) shows that the signs of the coefficients correspond to the character of the experimental curves shown in Fig. 4. That is, an increase in the pressure and the time of its application leads to a decrease in the moisture content of the material. However, the "+" sign in the coefficients of the second-order members indicates the decreasing nature of the magnitude of this influence.

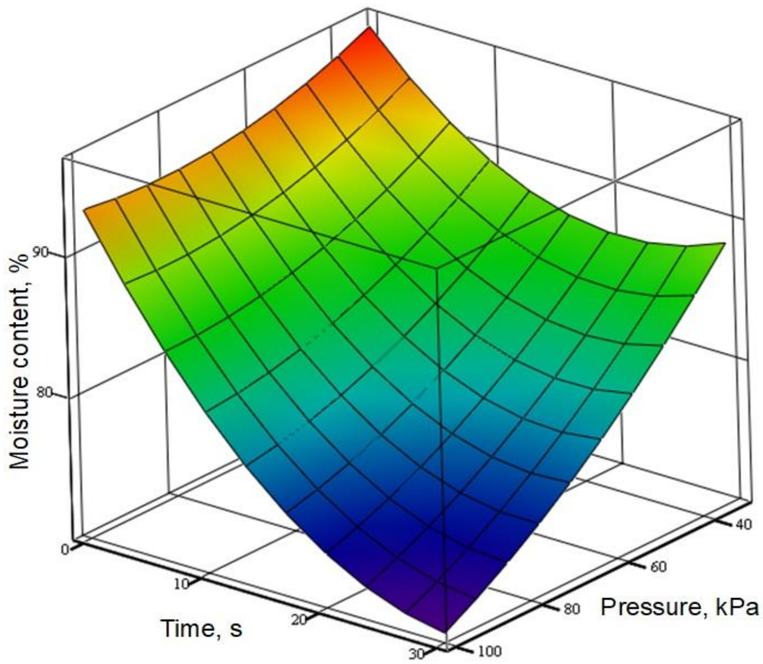

Fig. 5. **Response surface is built according to the regression equation (1)**

Thus, the results obtained show that the use of mechanical dehydration can reduce the moisture content of sapropel from 94% to 72-74% at a sample pressure of 80-100 kPa and a holding time under load of 22-26 s. In this case, the content of dry matter will increase from 6% to 26-28%, i.e. approximately 5 times. Subsequently, it is advisable to dehydrate such material in geotubes in accordance with the second stage described in the graphical dependences of Fig. 4. The use of mechanical dewatering as the first stage will make it possible to increase the yield of solid matter per unit volume of the geotube by up to 5 times, and therefore reduce the required volume and area under them. The use of mechanical devices for dewatering can be realized both with the use of well-known screw presses and with the implementation of the scheme described in [6].

Conclusions

1. Sapropel is an important resource for stabilizing the fertility of sod-podzolic soils in the Volyn region of Ukraine.
2. Mechanical compression of samples of organic sapropel from Zyatske Island, Volyn region, with a force of 80-100 kPa for 22-26 s can reduce its moisture content from 94% to 72-74%.
3. It is advisable to use mechanical dewatering as a preliminary stage to dewatering in geotubes, which will increase the yield of solid matter per unit volume of the geotube up to 5 times.
4. The use of the research results in mechanical devices for dewatering can be realized both with the use of well-known screw presses and with the implementation of the scheme described in [6].

Author contributions

Conceptualization, I.T.; methodology, I.T. and S.K.; software, I.T.; validation, V.D. and S.Y; investigation, I.T., S.K., V.D. and S.Y.; data curation, I.T and S.K.; writing – original draft preparation, I.T.; writing – review and editing, V.D. and S.Y.; visualization, I.T. and S.K. All authors have read and agreed to the published version of the manuscript.

References

[1] Шевчук М.Й. Сапропелі України: запаси, якість та перспективи використання (Sapropel of Ukraine: reserves, quality and perspectives of use). Lutsk: Nadstyr'ya, 1996, 383 p. (In Ukrainian).

[2] Baksiene E., Asakaviciute R., Romanovskaja D., Tripolskaja L., Razukas A. The influence of lake sediments on sandy loam soil properties and crop yield. Romanian Agricultural Research, no. 32, 2015, pp. 183-190.

[3] Stankevica K., Burlakovs J., Klavins M. Organic rich freshwater sediments (sapropel) as potential soil amendment for recultivation of areas contaminated with heavy metals. GeoConference on Water Resources, Forest, Marine and Ocean Ecosystems, 2013, pp. 595-601. DOI: 10.5593/SGEM2013/BC3/S13.016.

[4] Stankevica K., Vincevica-Gaile Z., Klavins M. Freshwater sapropel (gyttja): Its description, properties and opportunities of use in contemporary agriculture. Agronomy Research, vol. 14 (3), 2016, pp. 929-947.

[5] Koutev V., Hiebaum G., Sinaj S. Investigations on the fertilizing capacity of bottom sediments from eutrophicated lake. Sustainable Organic Waste Management for Enviromental Protection and Food Safety, vol. 1, 2004, pp. 105-108.

[6] Шимчук О.П., Дідух В.Ф. Технологія шнекового способу добування сапрпоелю та його використання (The technology of the auger method of mining saprpoel and its use). Lutsk: LNTU, 2013, 136 p. (In Ukrainian).

[7] Дідух В.Ф., Цизь І.Є., Грабовець В.В. Дослідження кінетики сушіння сапропелю (Study of drying kinetics of sapropel). Visnyk of the Lviv State Agrarian University: Agricultural Engineering Research, № 8, 2004, pp. 122-128. (In Ukrainian).

[8] Mihoubi D., Vaxelaire J., Zagrouba F., Bellagi A. Mechanical dewatering of suspension. Desalination, vol. 158(1-3), 2003, pp. 259-265.

[9] Mazzi F., Kramme G. Wiederbefeuchtung bei der pressfiltration. Chemie Ingenieur Technik, vol. 92(11), 2020, pp. 1851–1856. DOI: 10.1002/CITE.202000105.

[10] Rumky J., Visigalli S., Turolla A., Gelmi E., Necibi C., Gronchi P., Canziani R. Electro-dewatering treatment of sludge: Assessment of the influence on relevant indicators for disposal in agriculture. Journal of Environmental Management, vol. 268, 2020, pp. 1-10. DOI: 10.1016/J.JENVMAN.2020.110689.

[11] Ardila M.A.A., de Souza S.T., da Silva J.L., Valentin C.A., Dantas A.D.B. Geotextile tube dewatering performance assessment: an experimental study of sludge dewatering generated at a water treatment plant. Sustainability, vol. 12(19), 2020, pp. 1-22. DOI: 10.3390/SU12198129.

[12] Muller M., Vidal D. Comparison between open and closed system for dewatering with geotextile: field and comparative study. World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering, vol. 13, no. 10, 2019, pp. 627-632.

[13] Weggel J.R., Dortch J., Gaffney D. Analysis of fluid discharge from a hanging geotextile bag. Geotextiles and Geomembranes, vol. 29, 2011, pp. 65-73.

[14] Cantrell K.B., Chastain J.P., Moore K.P. Geotextile filtration performance for lagoon sludges and liquid animal manures dewatering. Transactions of the ASABE, vol. 51 (3), 2008, pp. 1067-1076. DOI:10.13031/2013.24526.

[15] Tsiz I., Homich S. Experimental research of working process of pneumatic intake device for sapropel extraction. INMATEH, Agricultural Engineering, vol. 40, No. 2., 2013, pp. 67-72.