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Drying Processes of Wet Materials: Environmental Problem and Choice of the Theoretical, Circuitry and Experimental Directions of their Solutions

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Abstract

Production of paper pollutes the environment. Various methods are created for the solution of this problem. In this paper a method of production of heaters from production wastes of paper has been offered.

Keywords: pulp, paper and board industry; the recovered stock; cellulose production

INTRODUCTION

Rather large number of the moisture containing environments which are initial material at production on a production basis of environmentally friendly products which are widely used in construction business are known now.

The known ways of production of the specified products are especially sensitive to initial material moisture content. The Excess of admissible norms (30-50%) leads to essential decrease in such indicators of quality of products as heat conductivity, durability, resistance to different fungal defeats, etc.

Besides, initial materials are waste of various productions (for example pulp-and-paper) which pollute the environment. Their regeneration is complicated or almost impossible without corresponding, enough prompt and expensive actions. The immensity of this work on regeneration of waste, decrease or elimination of their negative impact on ecology has been considered on the example of decrease in negative impacts on the recovered stock environment.

For a start it is necessary to consider scale of such influence, using separate data on the paper-mill producing up to 800 thousand tons of paper a year. A lot of waste in the recovered stock form makes 50 thousand tons at such outputs that demands the corresponding expenses at their export for the ground and will lead to environmental pollution. Waste is very difficult regenerated in a fertile layer under natural conditions, and his separate fractions remain practically in an initial state, leaving, thus, the busy territory unsuitable for use in agriculture or gardening.

For a detailed demonstration of negative and positive features of pulp-and-paper production and their influence on an ecological situation separate and most important characteristics of this production are provided.

The pulp-and-paper industry is the most water capacious. At the similar enterprises nearly 9,5 million m^3 of water are spent every day. Specific costs of water for various technological processes vary depending on the range, quality of production and the outputs. For example, sewage by production of 1 ton of paper which is developed from unbleached cellulose, is formed by from 10 to 50 m^3, and from the bleached cellulose – from 150 to 250 m^3.

It should be noted that during the work of the enterprise of a pulp, paper and board industry (PPBI) a significant amount of mineral and organic substances gets to sewage. For example, in the course of receiving 1 ton of fibrous raw materials from 40 to 1500 kg of organic substances passes into solution. These substances get to reservoirs in the absence of modern system of sewage treatment. Besides, the weighed fibers get to PPBI sewage as a result of washings, sorting, dilution.

The tabulated data on a specific consumption of water which vary depending on type of the produced paper density of a paper cloth and its ability to detain small particles are provided further (Table 1).

Table 1: Specific consumption of water by production of different paper types

Paper type	The volume of water is at 1 ton of paper, m^3
Newsprint	50
Printing:	60
Craft	75
Glassine	160
Base for waxing with paraffin	200
Copy-paper	350
Tissue-paper	350

The type of paper affects composition of sewage and, therefore, structure of waste which are formed at purification of this water.

The structure of waste sewage represents set of fiber of cellulose, paper, fillers, dyes, latex, emulsions, adhesives, etc. The specified structure of waste is defined by features of production.

There is classification according to which distinguish acid (sulphitic) and alkaline (sulphatic) ways of production of cellulose. At application of a sulphatic way there is a possibility of receiving cellulose from deciduous breeds of wood while sulphitic assumes a possibility of receiving cellulose only from coniferous breeds.

Feature of PPBI sewage which is formed at a sulphatic way of receiving cellulose is the content in waters of diverse substances: about 35% – inorganic substances (sodium sulfate, chloride, free alkalis, a carbonate) and about 65% – organic substances (oxyacids, lactones, phenols, resin and fatty acids, a lignin, formic acid, acetic acid).

At application of a sulphitic way of production of cellulose sewage contains about 10% of inorganic and about 90% of organic substances. Among inorganic substances ligninsulfonew acids, polysaccharides, monosaccharides, and products of disintegration of sugars, and also pitches, proteins and acetic acid are the most widespread. All this enters the deposit designated by the term "the recovered stock".

Recovered stock is a fibrous deposit of sewage of pulp-and-paper production which settles on filters of treatment facilities in the course of cleaning. Such deposit is composite material which contains together with earlier noted other components of raw mix for paper production: water, structure-forming element, mineral filler and various additives.

Chemical recovered stock composition is given in Table 2.

Table 2: Chemical recovered stock composition

Chemical composition, mass %							Content of oxides, mg/kg		
Total nitrogen	Phosphorus	Cellulose	Lignin	Calcium	Ammonium nitrogen	Carbon	CaO	Ka_2O	MgO
0,2-0,8	0,09-0,14	27,4-35	27,4-35	1,3-2,68	36,5-2,68	44,8-46	250	160	30

Main recovered stock characteristics in the form of fractions are given in Table 3.

Table 3: Recovered stock characteristics

Fractions, mm	Density, g/sm^3	Paper ash content, %	Color
>0,1	-	-	-
0,63-0,1 0,025-0,63	0,35	14-15	Gray
<0,025	-	-	-

Degree of dispersion is measured by the Shopper-Rigler device on state standard 14363.4-89 "A method of preparation of tests to physicomechanical tests" and has made 60-63° (In pulp and paper industry degree of dispersion of fibrous materials is measured in degrees.).

Follows from tabular data that the most part of mass of a deposit is made by cellulose fibers from shares of inorganic and organic impurity and also that the basic structure-forming element of a deposit is the cellulose fiber representing polysaccharide - one of the most widespread natural polymers. It is the main component of cellular walls of the higher plants and therefore raw materials of technological processes of production of paper is wood as the content of cellulose in fabrics of wood fluctuates from 45 to 60%.

The analysis of the characteristic of PPBI sewage rainfall is necessary for development of technology of recycling: it is necessary to investigate in addition some features of structure of raw mix for production of paper.

Cellulose fibers less than 3 mm of fibrillyarny capillary and porous structure is applied at the PPBI. Density of the cellulose used in production makes from 1,15 to 1,60 g/sm^3. According to applied researches, primary structure members of a cellulose fiber is microfibrilla, macromolecules generatrixs filched the form. The specified structure creates rather great difficulties when drying the recovered stock.

The mineral filler which according to requirements of technological process has to be insoluble in water and is chemically inert is entered into raw mix for improvement of quality of the products at the PPBI. The filler is entered in a fine state in order that it was distributed in a time between fibers and gave to paper the improved printing properties. As a rule, as a mineral component the kaolin is used, natural plaster, talc, chalk and compounds of titanium is more rare.

The cellulose flocculating of fiber in water by addition of electrolytes is carried out for achievement of stronger spatial structure of damp cellulose weight and integration of her small weighed particles at the PPBI. Addition of electrolytes reduces cellulose ξ-potential, at the same time mutual pushing away of fibers disappears that promotes increase in durability of raw weight and gives the chance to increase the speed of formation of spatial structure of this weight. Thus sulfate alumina, sulfate of aluminum or hydroxychloride of aluminum gets into composition of raw mix for production of paper depending on technological features of the concrete enterprise. Thus, the main sources of pollution of the hydrosphere and pedosfer in sulfate - cellulose production are blanching, cooking and acid shops. In the course of cellulose blanching traditionally use either chlorine, or it's derivatives (chlorine oxide, chlorates and hypochlorites), and at a delignifikation of the wood containing phenolic fragments a lignin (which content in wood of deciduous breeds of 20 - 30%, in coniferous breeds – to 50%) interacts with chloric reagents, forming dioxine and furana (or their predecessors) who are highly toxic ekotoksikant.

Starched paste is entered at the PPBI for increase in strength characteristics of products into raw weight in the quantity which isn't exceeding 1-3% of mix lump. Addition of starched paste leads to increase in durability of standard sheet to 15%. Instead of starched paste at the enterprises additive of a guaran or karubin can be used.

The listed mix components which are used for production of paper in certain ratios are washed away from raw weight, because of formation of a paper cloth in the water environment. In this regard sewage contains a significant amount of small fiber, the filling substances and elements of dyes which are added for giving of color shades to cellulose weight at the PPBI. The necessary color shade is reached by use of acid dyes from sodium salts. Average loss of components which separate from raw weight with waste water makes from 25 to 40% of all solid substances of mix. Similar loss of expensive input products involves negative impact on the environment.

Small particles are late with increase in a layer of weight which has settled on a filtrational grid of the car which produces paper, at a water filtration as the accumulating paper plays a role of an additional filter-bed. In this regard, because of the finely divided, the greatest number of the weighed substances gets to sewage at the beginning of process of formation of a paper cloth when the filtration through a grid of the papermaking machine goes without existence of the filtering fibrous layer from the particles detained by a grid.

After that the filtration of sewage is carried out for the purpose of catching of the weighed particles for prevention of their hit in reservoirs at the PPBI. The collected deposit (recovered stock) has firm structure and humidity about 95%. The recovered stock is utilized by export on specialized dumps and grounds. As a result of accumulation of layers of withdrawal in a dump obstacles for access of oxygen to the soil are created that makes negative impact on the most active consumers of oxygen in the soil - bacteria, microorganisms and plants.

Dumpings into the rivers and the soil from the PPBI increase the content of the weighed substances, sulfates, chlorides, oil products, organic compounds, a number of metals, substances the metoksilnykh, carboxyl and phenolic groups. In these maximum allowable concentrations parameters are exceeded several times.

The most dangerous and deserving further consideration toxins are dioxine and furana.

Use of recovered stock in the form of raw materials by production of useful production for avoidance of negative consequences from utilization of it is offered. By researches it is established that the dehydrated recovered stock can be applied as heat-insulating material. But similar application demands dehydration of waste. From the reached level the technician various methods of dehydration of the moisture containing materials are known. We will concern them in the form of the short analysis of merits and demerits.

The famous invention "The device for electroosmotic dehydration of materials" is known [1,2]. Need of existence of the vacuum chamber is an essential lack of the proposed technical solution. The transporting mechanism (which is executed in the form of the screw) complicates technical solution. Need of transmission of the rotational moment raises energy consumption on process of electroosmotic production.

The formula of the useful model "The Device of Removal of Moisture from Porous Materials" is known [3]. Need of existence in the device of the electroosmotic pump which is capable to support a continuity of a uniform stream of liquid between channels of the pump and a tube of giving of microamounts of liquid is a drawback of the presented technical solution. In the same time liquid separates unevenly depending on electric field strength and force of electric current and electric conductivity of the dehydrated weight. Similar comes at electroosmotic dehydration from interelectrode space.

The useful model "The Device of Deleting Moisture from Porous Materials" [4] is known. The technical result which is specified in a patent prototype is reached due to maintenance in the device of two electrodes, a voltage source, the camera for drying and the device for deleting moisture from porous material (the adjustable electroosmotic pump). Time of the drained material (for example, wood) have been used as capillaries of this pump. This constructive decision considerably complicates installation, brings a number of technical restrictions for dehydration of porous materials besides wood (for example, damp recovered stock) as capillaries of fine particles won't be able to provide high-quality and fast removal of liquid. It has been defined that the electrode extending moisture has to be functionally and is structurally combined with the vacuum device (consisting of the vacuum pump and the backpressure valve connected to the atmosphere) and the heating device which create an additional and considerable consumption of energy resources at which dehydration can be equated by electroosmosis by means of the device of removal of moisture on expenses to thermal or thermomechanical drying. This conclusion confirms expediency of an exception of vacuum or heating devices in the course of dehydration of porous materials with electroosmosis, besides the technical result achieved due to use of these devices can be reached without their application.

The problem of safety of operators who serve the corresponding devices of drying which are under voltage arises during the work with damp material (recovered stock). This risk can be excluded if to use voltage on drying device electrodes not dangerous to the person.

When developing technology of dehydration of porous structures on the basis of electroosmosis and at her realization there are other difficulties which concern the analysis of the physical processes resulting in materials, and the choice of parameters of control (check) of functional compliance (quality) of material of a product from the recovered stock.

The known result which represents the speed of the movement of particles in the studied environment undertakes the beginning of the analysis of electroosmotic dehydration

$$V_0 = \frac{\xi \cdot \varepsilon \cdot \varepsilon_0 \cdot I}{\lambda \cdot \eta}, \quad (1)$$

where ξ – electrokinetic potential;

ε – dielectric permeability of the environment;

ε_0 – dielectric constant;

I – electric current intensity;

λ - specific electric conductance of liquid;

η - viscosity of the environment.

This expression contains a number of parameters which are difficult for estimating in utilitarian applications for the concrete environment. Therefore it is expedient to pass to phenomenological (integrated) parameters which will be considered when developing technological process of production of ecoplates, ecologically safe..

From expression (1) it is visible that such parameters which define current I can be tension U, which creates current I in the environment with electric conductance g. We will show it. From (1) we have

$$I = \frac{V_0 \cdot \lambda \cdot \eta}{\xi \cdot \varepsilon \cdot \varepsilon_0} \quad (2)$$

At temporary changes of parameters (2), for example $\lambda(t)$, $\varepsilon(t)$, I will also change therefore it is possible to write down current as function from time

$$i(t) = \frac{V_0(t) \cdot \lambda(t) \cdot \eta(t)}{\xi(t) \cdot \varepsilon(t) \cdot \varepsilon_0}. \quad (3)$$

It is known that current $i(t)$ depends on electric conductance $g(t)$ environment and the enclosed tension U, т.е.

$$i(t) = g(t)U \quad (4)$$

Then from (3) and (4) expression turns out

$$g(t) = \frac{1}{U} \cdot \frac{V_0(t) \cdot \lambda(t) \cdot \eta(t)}{\xi(t) \cdot \varepsilon(t) \cdot \varepsilon_0}, \quad (5)$$

which at $U=const$ phenomenologically expresses all dynamics (3).

At change in the environment, for example, at the expense of dehydration, at some stage (t_k) the state which is characterized by a condition will come

$$g(t_k) = const = \min \quad (6)$$

what is equivalent to the condition more convenient for control in practice

$$i(t_k) = const = \min. \quad (7)$$

The received results allow to plan an experiment which isn't labor-consuming and allows to choose the direction of search of technical solutions of realization of process of electroosmosis. Schematically the experiment can be presented, estimating dependences (4), (6), (7) (Fig. 1).

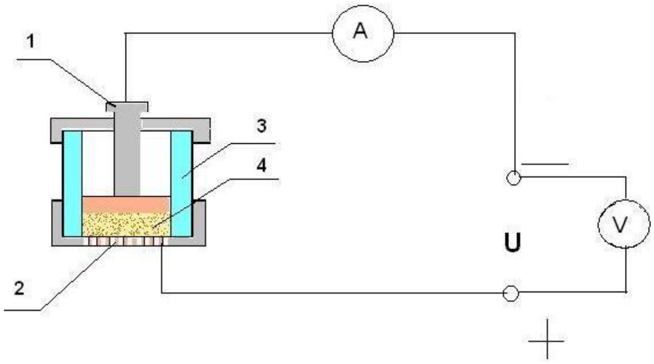

Figure 1: 1 – anode, 2 – cathode, 3 – the case from insulating material, 4 – research environment, A – ampermeter, V – voltmeter

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It is possible to estimate temporary parameters of process of change of properties of the studied environment which in an integrated form are presented along with *i(t)* a variation of mass of the studied environment $\Delta m(t)$

$$\Delta m(t) = m_0 - m(t), \quad (8)$$

where m_0 – initial weight,

$m(t)$ – current value of weight.

In this case there is an opportunity to estimate correlation *i(t)* and *m(t)* or $\Delta m(t)$ ($r_{i,m}$>0,7) what will allow to use in the course of dehydration for control of his separate stages the parameter *i(t)* which can be regulated.

As a result of such experiment temporary ranks will be received

$$i(t) \in \{i(t_j)\} \quad (9a),$$

$$\Delta m(t) \in \{\Delta m(t_j)\} \quad (9b)$$

where $i(t_j)$ – value of change of electric current in timepoint t_j;

$\Delta m(t_j)$ – value of decrease of the recovered stock mass due to electroosmosis.

Expressions (8) and (9a, b) allow to express as formulas dynamics of process of dehydration and its duration at the chosen design of devices.

The experiment which has been made according to the scheme (Fig. 1) has shown that $\{i(t_j)\}$ and $\Delta m(t_j)$ are well represented by exponential models. Determination coefficients at the same time have made η_i = 0,862, $\eta_{\Delta m}$ = 0,913.

The stated research concerns circuitry aspects of realization of the offered dehydration method. The marketing strategy of advance of products from recovered stock in the conditions of modern economy is not less essential party. This question has been considered on the example of dynamics of requirements of the Russian branch of construction of heaters [5]. Along with it separate most important characteristics of products from various materials, and also elements of justification of economic feasibility of implementation of the considered project of production of ecologically safe production – insulating material from waste of paper production are provided.

Growth rates of construction in Russia increase from year to year. It is confirmed by the data provided by Federal State Statistics Service [5]. According to the provided data it is possible to tell that the number of the entered buildings from 2000 to 2016 has increased almost for 90%, and the total area of the entered buildings for the same period has increased for 121%. Growth of construction involves development of the industries producing construction materials including heaters.

According to data of it from regions of the Russian Federation regarded as the pilot region, demand for heaters in the last several years grows in high gear what data on sales of the main regional producers ("Ecovata" and "Penobeton") demonstrate to what confirms relevance of the chosen research subject (Fig. 2, Fig. 3).

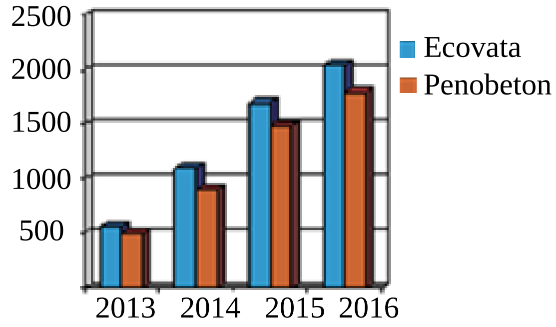

Figure 2: Sizes of the market of sales of construction materials in the considered region (10^3, m^3/year)

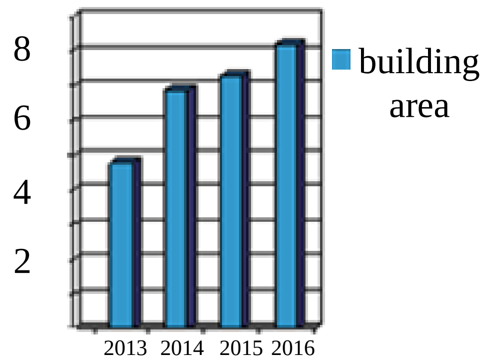

Figure 3: Sizes of the market of the construction which is subject to warming in one of regions of the Russian Federation (mln. m^2/year)

Waste mixes up with liquid glass binding, fire-retarding agent and an anti-septic tank in the course of implementation of the production technology of insulating material, is formed in plates of the necessary sizes and is affected by electroosmosis. Insulating material which is received thus has the sufficient durability, very low heat conductivity, well resists to rotting, isn't damaged by insects and rodents, are the good sound insulator. For reflection of elements of management of the organization of production which are connected with this technology it is necessary to emphasize uniqueness of the production technology of such heater which is in use as the main material of the dehydrated waste of paper production that allows to reduce prime cost of the final product considerably. These tables 4 [6] allow to assume that waste of paper

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production will be a stable and inexpensive source of raw materials for production of heat-insulating material.

Table 4: Formation of production wastes and consumption by types of economic activity across the Russian Federation

	Total, mil. t.	Pulp, paper and board industry, mil. t.
2009	2991,2	6,8
2010	3519,4	6,5
2011	3899,3	5,6
2012	3876,9	6,9
2013	3505	5,3
2014	3734,7	5,7
2015	4303,3	6,1
2016	4712,1	6,9

Due to addition of such materials as liquid glass binding, fire-retarding agent, antiseptics, etc. are reached all properties, necessary for a heater, which are established during laboratory researches [7] which results are given in Table 5. The final product in comparison with analogs has prime cost twice lower, qualitatively without conceding by the main criteria at all [8]. Besides, this heater is eco-friendly as for 80% consists of the cellulose fibers not suitable for production of paper for technical reasons, is respectively absolutely safe for the person that is confirmed with laboratory researches.

Table 5: Competitive advantages

	Thermal conductivity, W/m*K	Density kg/m^3	Moisture absorption, g	Prime cost, rub. for 1 m^3
The offered product, ECOslab	0,039	510	0,52	1500
Cellulose wool	0,058	720	15,4	4700
Autoclaved lightweight concrete	0,072	830	3,8	8300

The subject of the offered technology belongs to the list of the priority directions of development of science, technologies and the equipment of the Russian Federation that also causes relevance of her realization [9].

At application of a technological innovation in the form of production of a heater from waste (the recovered stock) with addition of liquid glass binding, the end result which production of unique production – the heater with competitive characteristics answering to modern criteria of quality is achieved [10].

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