INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN, 1/2021 (19): 37–43

POSSIBILITIES FOR UTILIZATION OF WASTE WATER AND RESIDUAL WOOD FIBRES IN THE PRODUCTION OF HARDBOARDS

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ABSTRACT

Despite the continuous introduction of new materials and technologies in the production of wood-based composites, hardboards (HB), remain in the range of wood products, due to their good consumer and exploitation properties. The production of these products is characterized by the intensive consumption of raw materials. In the wet production process, much of the raw material used is taken up by water involved in the formation of the wood-fibre mat. It forms a significant share in the value of the finished product, resulting in a smaller added value. At present, the utilization of wastewater from the production of the HB is unsatisfactory. Its high fibre content creates sludges that can be recycled or thermally utilized. The present study is aimed at reviewing the possible methods of utilizing the wastewater and fibre sludge in it. This will provide the Bulgarian producers with a means of enhancing production efficiency and applying the circular economy principles.

Key words: utilization, wastewater, wood fibres, circular economy.

INTRODUCTION

The global pulp, paper, paperboard, and wet-process fibreboard production in 2019 was estimated to approximately 621 million tons, with the USA and China being the major producers (Forest Product Statistics). Consequently, these production facilities generate substantial amounts of non-hazardous sludge and solid waste, requiring further waste management or utilization as by-products (Ochoa de Alda, J.A.G 2008). Currently, the main methods of disposal of the primary sludge are landfilling or burning for energy generation. However, due to the stricter environmental legislation and increased landfilling costs in the EU, the industry is searching for alternative waste management methods.

Most of the suspended solids are removed during the primary mechanical wastewater treatment, and the resulting liquid sludge contains large quantities of residual wood fibers as the main organic components (Ochoa de Alda J.A.G. and Torrea J.A. 2006; Ochoa de Alda, J.A.G 2008,], thus representing a potential feedstock for manufacturing wood-based panels (Davis, E. et al. 2003; Geng, X et al. 2007; Migneault, S. et al. 2010). The residual fibers are significantly different in composition, even between factories using the same pulp and paper production technologies (Scott G.M. and Smith A. 1995; Simão, L. et al. 2018).

The utilization of waste in the Bulgarian woodworking industry is a problem of constant relevance. In recent years, the problem of wood raw materials has become very difficult for many wood-processing companies. Uncertainty in the national and international economy requires high production efficiency and cost savings.

Circulation flows (close-loops) in the context of the circular economy have become a leading sustainable alternative for improving the supply of input resources. Hardboards (HB) production, wet-process fibreboards, includes a variety of raw materials - from water to chemicals for resin production. On the one hand, this feature forms a large capital intensity of production, and on the other hand opens opportunities for the application of the circular economy principles and methodological framework. The present work aims to identify possible options for the reuse of wastewater and wood fibres from the production of HB. The object of the research is an enterprise for the production of HB in Bulgaria, representing a typical example of the need for supply improvement in the context of a circular economy.

THE CIRCULAR ECONOMY AS AN ALTERNATIVE FOR MATERIALS SUPPLY

Circular economy (CE) lies on close-loops (Jawahir, 2016), waste in many types of its appearance is recovered (Gregson et al., 2015), and the exhaust materials are turned into resources (Valavanidis, 2018). Being an alternative, the circular economy lies on the economic (resource) efficiency (Geldermann et al., 2016) and the so-called consequent business model (Ionescu et al., 2017). This means that the implementation of the CE as an activity in every day enterprise operations causes benefits and costs (see Kharazipour and Kües, 2007; Daian and Ozarska, 2009; Lagray, 2009). In many cases, it comprises the decisions in strategic levels and as McCormick and Kautto (2013) state – in the phase of planning. The most common in the research on the CE implementation in wood processing is focused on the cascading of wood residues (Risse et al., 2017) or the topical problem of scarcity (Mair and Stern, 2017).

Currently, the utilization of wood waste has been focused on research topics and the practice of particleboard production (Faraca, 2019), to some degree to MDF production (Daian, 2009) and the other panels have not been profoundly investigated. In the context of the present study, wastewater recovery should be considered as recycling. Recycling is focused mostly on fibres (Antov and Savov 2019, Antov et al. 2019), which is appropriate for the sludge and panels (Wang, 2014; Roffael et al. 2002, Roffael et al. 2010, 2016, Mantanis et al. 2004). This kind of utilization should create the so-called inner-circles (Ellen-MacArthur-Foundation, 2013).

MATERIALS AND METHODS

Methods for evaluation of investments and making managerial decisions under uncertainty were used in the present study. Investment alternatives are elaborated with the information given by the enterprise investigated. The enterprise is the biggest producer of hardboards in the country. The enterprise can apply wastewater recirculation after the production stages. Significant costs related to the treatment of wastewater are made each year. Almost 75% of water is being treated inside the internal treatment plant and the remaining part (25%) of the water is being relocated to the external plant. There are several possibilities to recirculate the water and each of them causes costs and benefits. The costs are calculated as follows:

Costs for exploiting the new system for wastewater recirculation:

$$\boldsymbol{C1 = c_{rec}.V_i.S}, \qquad (1)$$

Where c_{rec} are costs per m^3 water supplied to the basin after the completion of the operation i, mechanically treated and transported again to the operation;

V_i – the volume of the wastewater outgoing after the operation *i*.

S – the share of the wastewater after the operation *i* being recirculated.

Costs for internal treatment:

$$C2 = c_{int}.V_i.0,75.(1-S) \quad (2)$$

The costs C2 are corrected with the share of water being internally treated. The volume of the water being fed to the treatment plan is reciprocal to this supplied to the basin.

$$C3 = p.V_i.0.25.(1-S) \quad (3)$$

Where p is the price per m^3 water supplied to the external treatment plant after the completion of the operation *i*.

Determining the benefits is a more subjective process. In the theory the benefits could be economies in the new process appeared after the implementation of some rationalization. The benefits in the current study are derived from the water being recirculated and consequently saving money due to less intensive wastewater flow fed to the treatment plant per period. The equation is as follows:

$$B = \frac{C2+C3}{1-S} - C2 + C3 \quad (4)$$

The costs for recirculation are assumed to be proportional to the share of recirculated water. They are derived from the costs for the internal treatment of wastewater, but excluding the labour costs. The reason is that this intermediate cleansing process does not require particular workplaces. The tasks for controlling the new recirculation system can be incorporated into the job description of the current jobs.

RESULTS

The savings generated by the system per year are shown in Figure1. More water-intensive operations generate greater benefits to the enterprise.

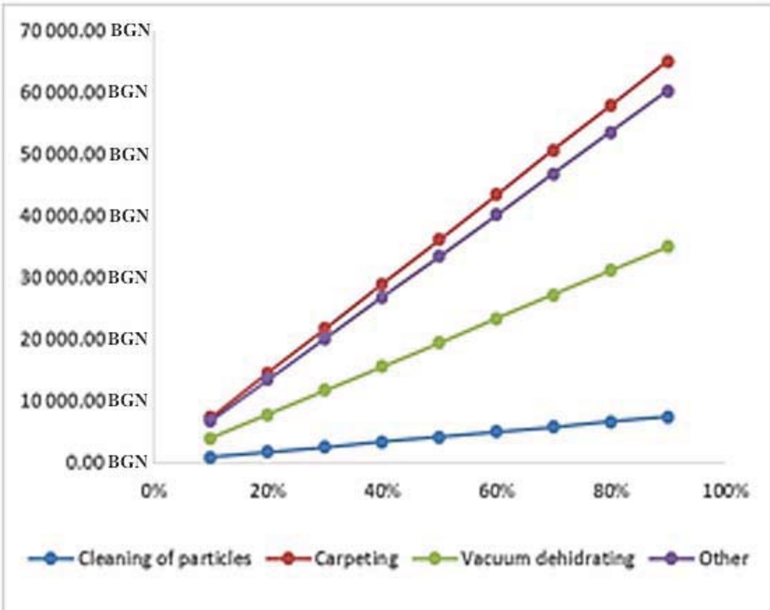

Figure 1: The economies from reducing the treated volumes per year in BGN currency

The graph shows that the water released during the laying of the wood carpet leads to the greatest savings if it is recycled. As the share of recycled water increases, the importance of water-intensive operations increases. The study assumes that as the share of recycled water increases, the operating costs of the system increase proportionally. In the enterprise - an object of study, the costs for maintenance of the system without those for labour are constant. Therefore, it can be expected that when building an installation with a volume corresponding to a certain recycling rate, the operating costs will be constant. As shown in the figure, the recycling of all operations enhances the effect of recycling as much as possible wastewater is fed to the system. The annual amount of the economies is about 21 371 BGN. That means that the system can reduce the costs for external treatment by about 30%–70%.

The main parameters of the calculation model applied are presented in Figure 2. During the research, it appeared that two break-evens exist in the enterprise's treatment and water supply system.

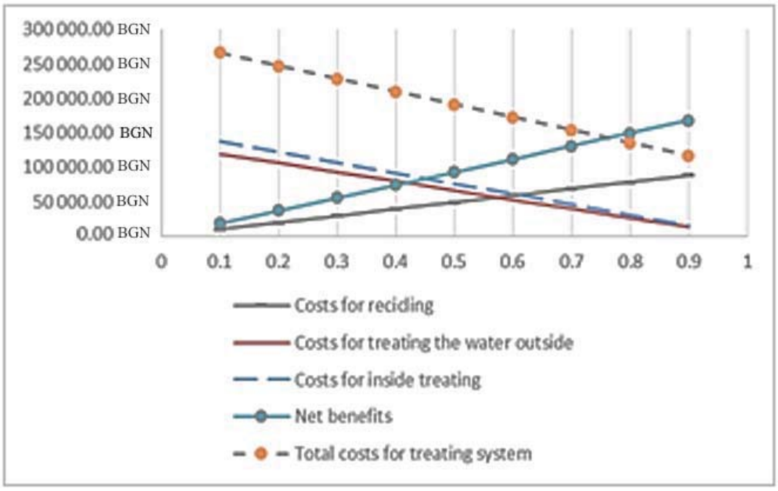

Figure 2: Graphs of the costs by types and net benefits of the recirculating system being estimated

As seen in Figure 2, the first break-even appears at the level of 45% recycled wastewater for all operations within the production process. After that level, the enterprise can expect that the recycling system should become efficient and it is worth building. After the second break-even, the recirculation system could generate lesser costs than the net benefits for the overall treatment system. Recirculation and reducing water volumes to the levels of 80% per given period, for example, a year, can generate economies sufficient to be improved the entire system for treatment. The second breakeven is highly theoretical, but it could appear if the new recycling system reduces the volumes fed to the internal treatment plant. After this point appear the questions about the organization of the entire process. The enterprise can improve the capacity of internal treatment.

Due to the ambiguous nature of the preliminary assessments here, the risk for investments in the installation for recycling the wastewater is calculated using the Hurwitz criterion (Jeantet and Spanjaard, 2009) with a 90% probability of failure. Results are presented in Table 1, along with the minimal parameters of the investments in the recirculating system.

Table 1: Results for the estimated framework of future investments in the recirculating system at 45% break-even

Operation type	Minimum investment costs, BGN	Possible operating costs, BGN/year	Possible net benefits, BGN/year	Risk level – marginal increment
Carpeting	36232	19 073	13043	low
Other operations	33528	17649	12070	low
Vacuum dehydrating	19468	10 248	7008	high
All operations	93338	49 135	33601	high
Cleansing of articles	4110	2 163	1479	low

Due to the ambiguous nature of the preliminary assessments here, the risk of failure of a particular alternative has been assessed by marginal increment between risks estimated through squared deviation between minimum values of net benefits and expected ones under the Hurwitz criterion. The results in the table show that there are individual operations that are critical to the results of the construction of the installation. These include carpeting and so-called other operations like mechanical dehydrating and pressing. The risk of investments comprised all the operations is high, but as was shown before, the net benefits are big and allow the enterprise to take additional measures in improving the water recirculation system. For all the investment alternatives the expected (forecasted) period of return is from 2 to 3 years. If the conditions improve, for most of them the return period would be almost a year.

Another advantage of wastewater recirculation is that the share of waste fibres will be significantly reduced. At present, despite the presence of flocculant, approximately 15 tons of fine fiber fraction are lost in 24 hours. These fibers are currently used for the production of heat energy.

CONCLUSIONS

The study showed that building a wastewater recirculation plant would be a very effective investment. The existing thresholds regarding the investments were found out. If the company management decides to invest in something small with less expenditure, the result could be almost invisible in the context of annual costs for treating. The installation should include at least the main water-consuming operations. Only by this way, the production process could generate scale economies to reduce costs and establish foundations for general innovations like treatment plant improvement, or other technological ones. In a deterministic manner, if the pessimistic criterion does not happen, the possible benefits for the enterprise can be more than 1% per year costs savings and consequently opportunities for reduction of unit costs for HDF being produced in the enterprise.

ACKNOWLEDGEMENTS

This research was supported by the project No. НИС-Б-1002/03.2019 'Exploitation Properties and Possibilities for Utilization of Eco-friendly Bio-composite Materials', implemented at the University of Forestry, Sofia, Bulgaria.

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UNIVERSITY OF FORESTRY

FACULTY OF FOREST INDUSTRY

INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

1/2021

INNO vol. IX Sofia

ISSN 1314-6149
e-ISSN 2367-6663

Indexed with and included in CABI

INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

Science Journal
Vol. 10/p. 1–92
Sofia 1/2021

ISSN 1314-6149
e-ISSN 2367-6663

Edition of
FACULTY OF FOREST INDUSTRY – UNIVERSITY OF FORESTRY – SOFIA

The Scientific Journal is indexed with and included in CABI.

Cover Design: DESISLAVA ANGELOVA

Printed by: INTEL ENTRANCE
Publisher address: UNIVERSITY OF FORESTRY – FACULTY OF FOREST INDUSTRY
Kliment Ohridski Bul., 10, Sofia, 1797, BULGARIA
http://inno.ltu.bg
http://www.scjournal-inno.com/

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INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN, 1/2021 (19): 5–6

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