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Scheduling for efficient reduction of fiber industrial evaporative lagoons

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In a hardboard plant, the black liquor produced during the panel's pressing is treated in a new evaporation unit, to concentrate the solids up to 25%.
Currently the concentrated black liquor from the evaporation plant goes to the evaporative lagoons to concentrate the solids up to 45%, by natural evaporation with subsequent burning in the furnace.
The aim of this study is to develop an integrated system that improves the natural evaporation in the lagoons, by increasing the black liquor's temperature. To achieve this goal two artificial ponds were built, where the black liquor is heated with the hot water from the condensers, avoiding also the intensive use of the cooling towers.
Therefore, two scenarios were studied for the heating of the black liquor. In the scenario 1 the two artificial ponds are used to heat the black liquor currently in the lagoons and during that period the effluent of black liquor from the evaporation plant goes to the lagoons. In the scenario 2 just one pond receives black liquor from the lagoons and the other one receives the effluent from the evaporation unit.
The comparison of these two scenarios with the present situation enabled us to conclude that the scenario 1 is the best choice, because it allows us to obtain 45% of solids in the lagoons in less time than the current scenario and the operation period of the forced cooling towers is lower than the one corresponding to scenario 2.
Therefore it is possible, with an integrated system, to achieve the solid content of 45% in the lagoons in 20 months, with the additional advantage of reducing the operational cost of the cooling towers.

1. Introduction

I.F.M., a hardboard manufacturer located in Tomar (Portugal) produces panels using eucalyptus as raw material. The fibres are obtained by a thermo-mechanical process where the wood chips are heated with steam before defibration. The panels formed in a wet line are pressed in a multi-stage press and sent to moisture absorption stabilisation chambers.
The black liquor produced in the multi-stage press is sent to a new evaporation plant for treatment. In the multiple-effect evaporation plant the black liquor circulates in counter

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current with vapour; fresh black liquor is fed to the last effect, and live steam to the first one. In the first effect where the heat exchanger receives live steam the black liquor reaches the highest solid concentration. In this effect vapour will be produced through black liquor evaporation and fed to the second effect using a vacuum pump for that purpose. This vapour will generate more vapour by black liquor evaporation in this effect, and in the other effects the process will be the same. The evaporation plant produces concentrated black liquor with 25% of solids. To increase this value, the concentrated black liquor is sent to lagoons where further natural evaporation will take place.

The existing lagoons of black liquor cause an environmental impact and strongly depend on the atmospheric conditions, especially during winter, as the rain fills the lagoons.

The aim of this work is to develop a system to increase the concentration of the black liquor in the lagoons up to 45%, a reasonable value that enables it to burn in a furnace.

To achieve this goal a new strategy was defined based on two industrial and operational modifications:

- A new evaporation unit for treatment was installed to improve evaporation, reducing the black liquor flow and increasing the concentration of solids;
- Two artificial concrete ponds were built to enhance the natural evaporation through the increase of the black liquor's temperature. The black liquor will be heated with the hot water from the condensers of the evaporation plant, which otherwise should be cooled in cooling towers. This integrated heating system increases the evaporation rate in the lagoons, saving energy and reducing operational costs.

2. Evaporation plant

In the past the old evaporation plant had only the capacity to treat 15m^3/h of black liquor, concentrating the solids up to 15%. As the process produces 20m^3/h of black liquor the remaining flow was sent directly to the evaporation lagoons at a very low concentration (3%) together with the concentrated black liquor. Therefore in the earlier period the evaporative lagoons receive 9m^3/h with 8% of solids. The new evaporation plant was built to improve the efficiency and the capacity to treat all the black liquor produced.

The new evaporation plant operates in a total counter-current flow with five evaporators, and it is able to treat the 20 m^3/h of the black liquor produced by the process, concentrating the solids up to 25%, and sending to the ponds or natural lagoons 2.4 m^3/h of residual effluent of black liquor.

3. Evaporation Rate and Current Scenario

The industrial evaporative lagoons are used to concentrate the solids up to 45%, in order to be able to feed it to the biomass furnace.

At the moment, there are about 20 lagoons, with a volume of 39618 m^3 and an area of 49477 m^2.

Due to their environmental impact and the necessity to comply with new strict regulatory norms, the aim of IFM is to create a programme to eliminate the lagoons.

The natural evaporation in the lagoons depends strongly on the atmospheric conditions, such as the air temperature and humidity, the precipitation, the wind velocity, the area of the lagoons and the temperature of the black liquor in the lagoons.
The evaporation rate, as a function of the black liquor's temperature in the lagoons and for different atmospheric conditions, is defined by the curves presented in figure 1, adapted from Moita at al. (2005) work. A sensitivity analysis showed that the wind velocity is the most significant atmospheric variable and greatly affects the evaporation rate.

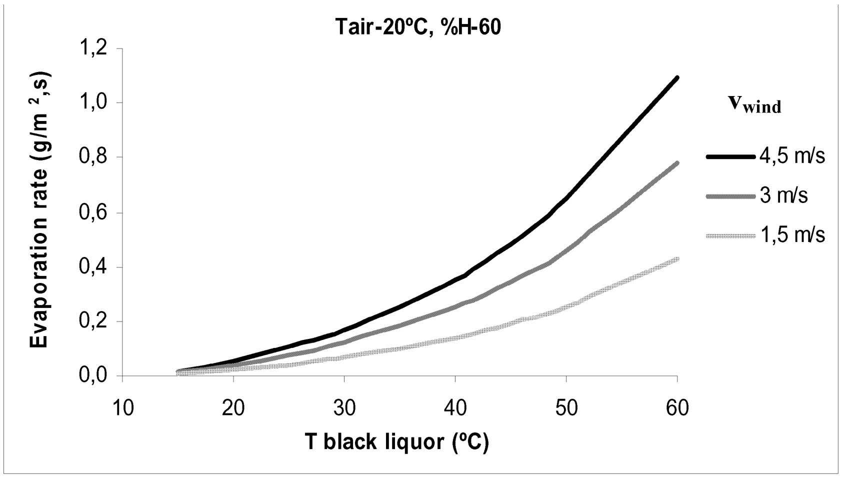

Figure 1 – Evaporation rate at three different wind velocities and as a function of the black liquor´s temperature

In the current situation the lagoons receive the black liquor from the evaporation unit, and only natural evaporation occurs.
Table 1 shows that evaporation rate strongly depends on the temperature of the black liquor and on the wind velocity, which greatly influence the time excepted for the elimination of the lagoons. Moreover when the temperature of the lagoon is less than 15ºC or the wind velocity is less than 3m/s the black liquor accumulates in the lagoons. The net evaporation is calculated abating to the evaporation rate from figure 1, an average annual precipitation of 0.024 $g/m^2.s$, obtained from meteorological data of that geographic region.

Table 1- Elimination time ($t_{elimination}$) and net evaporation rate (Net_{evap}) at different black liquor's temperatures ($T_{b.l.}$) and wind velocities (v_{wind})

Wind velocity (m/s) = 3 m/s			**T black liquor (ºC) = 20ºC**		
$T_{b.l}$ (ºC)	**Net_{evap} ($g/m^2,s$)**	**$t_{elimination}$(months)**	**v_{wind} (m/s)**	**Net_{evap} ($g/m^2,s$)**	**$t_{elimination}$(months)**
15	-0.011	∞	1.5	-0.002	∞
20	**0.015**	**28**	3.0	**0.015**	**28**
25	0.050	6	4.5	0.031	10

The net evaporation rate depends on the atmospheric conditions, so that in the summer the natural evaporation is higher due to higher temperatures and lower precipitation and in the winter the black liquor may accumulate in the lagoons, because of the lower temperatures.
For an average annual temperature of the black liquor in the lagoons of 20ºC and an average annual wind velocity of 3 m/s, it can be estimated that 28 months are needed to attain 45% of solids in all the evaporative lagoons.

4. Integrated Process

To achieve the elimination of the lagoons, two artificial ponds (pond 1 and pond 2) were built to enhance the natural evaporation, through the increase of the black liquor temperature. Each artificial pond has an area of 1250 m^2 and a volume of 625 m^3. The black liquor will be heated with the hot water from the condensers.
The vapour of the last effect of the evaporation is condensed with water countercurrent flow. This heated water should be refrigerated in the cooling towers before recirculating to the condensers.
Therefore, instead of cooling in the towers, this water will be used to heat the black liquor from the lagoons, leaving the towers in stand-by mode. Thus, the increase of the black liquor temperature will enhance the evaporation rate in the lagoons, allowing a faster elimination of the lagoons.
Additionally this integrated heating system puts the cooling towers in stand-by with subsequent energy savings and reduction of operational costs.
A study of different scenarios was carried out to find the best alternative, taking into account the minimum operational costs due to higher stand-by time of the cooling towers and the reduced treatment period using the ponds.

5. Comparision of Scenarios

The scenarios studied were made considering the new evaporation unit working at nominal conditions.
Therefore in all scenarios the system receives from the evaporation unit an effluent flowrate of 2.4 m^3/h with 25% of solids.
The net evaporation rate was calculated taking into account the annual average precipitation.
The lagoons and artificial ponds are considered treated or eliminated when the content of solids achieves 45%, which is the necessary concentration to burn the black liquor.
To describe the operation of the artificial ponds four different stages were considered; the stage of filling the ponds, the heating stage of the black liquor, the treatment period to obtain the 45% solids content and the harvesting stage of the ponds.
The natural evaporation of black liquor in the lagoons was considered during the entire horizon.

5.1 Scenario 1

In this scenario pond 1 and 2 receive the effluent flow from the lagoons, but they are heated with hot water from the condensers one at a time.

When the concentration of solids in the pond achieves the 45%, the pond is harvested and refilled with black liquor from the lagoons.

During the treatment, the level of black liquor in the ponds is kept constant, by the continuous addition of black liquor from the lagoons. The evaporation plant effluent of about 2.4 m^3/h, with 25% of solids, goes directly to the lagoons.

When the pond 1 is at harvesting time, the black liquor of the pond 2 is heated. Therefore, in this scenario the cooling towers only operate when the time to concentrate the solids up to 45% is less than the sum of the time to fill, to heat and to harvest the other pond. This happens when the concentration of solids in the lagoons is high, which leads to a shorter time to achieve the solids content of 45% in the ponds.

After heating, the temperature of the black liquor in the ponds was estimated to be 35ºC. The evaporation rate in the ponds is calculated at this temperature while the evaporation rate in the lagoons is determined at 20ºC.

In the scenario 1 the total time, estimated by the resolution of the dynamic model, to achieve the elimination of the lagoons is about 20 months. During this period the two ponds are refilled 13 times, and the cooling towers need to operate for around 497 hours.

5.2 Scenario 2

In this scenario pond 1 receives the flow from the evaporation plant while pond 2 receives black liquor from the lagoons. Only pond 2 will be heated with the hot water from the condensers.

The level in pond 2 is kept constant, due to the addition of black liquor from the lagoons.

The black liquor temperature in pond 2 was considered to be 35ºC whereas the lagoon's temperature was 20ºC.

When pond 1 is full, it has to be harvested and at this point the concentration of solids is about 43%, concentration at which the black liquor must be burned in the furnace.

During the harvesting time of pond 1 the flow from the evaporation plant has to go to the lagoons.

In this scenario, whenever pond 2 has to be harvested the cooling towers will start to operate.

The resolution of the dynamic models describing this situation allows the calculation of a total time of 16 months, to achieve the elimination of the evaporative lagoons. In this scenario pond 1 is refilled 18 times while pond 2 is refilled 8 times and the cooling towers have to operate for 1344 hours.

6. Results

Table 2 summarises the results for the different scenarios studied. If the integrated system is not implemented the lagoons will achieve a solid's content of 45% only after 28 months and during this period the cooling towers are always in normal operation with the inherent operational costs.

In the two scenarios with heated black liquor the operation time of the cooling towers is lower than in the current scenario.
The comparison of scenarios 1 and 2 has to take into account not only the elimination time of the lagoons, but also the cooling towers operation costs plus the harvesting costs of ponds.
Since in scenarios 1 and 2 the total number of harvesting operations is the same the choice of the best scenario depends on the lagoons elimination time and on the cooling tower's operation time.
The scenario 1 has the lower cooling tower's operation time, but the elimination time is higher than in the scenario 2. Therefore to achieve 45% of solids in the lagoons it will be needed 20 months in scenario 1, but only 16 months in scenario 2. However, in scenario 1 the operation time of the cooling towers is about 3 times lower than in scenario 2.

Table 2- Elimination time, number of ponds harvesting and cooling towers operation time for the three scenarios

Scenarios	**Elimination time (months)**	**Pond 1 harvesting events**	**Pond 2 harvesting events**	**Total harvesting events**	**Cooling towers operation (h)**
Current	28	-	-	-	20261
1	20	13	13	26	497
2	16	18	8	26	1344

In the future, when all the evaporative lagoons will be treated, the two built artificial ponds will have the capacity to receive all the effluent from the evaporation plant.
Moreover, if the evaporation plant has to be stopped for any reason, the two new ponds will have the capacity to receive the effluent during 3 days considering the average effluent flowrate of 20 m^3/h.

7. Conclusions

This study shows that the integrated process promotes the natural evaporation in the lagoons by increasing the effluent black liquor's temperature.
The best scenario to achieve the reduction of the evaporative lagoons is scenario 1 in which, despite the fact that the elimination time is higher than in scenario 2, it has the advantage of the operational time of cooling towers being about 3 times lower than in scenario 2. This makes the scenario 1 the most economical and efficient procedure to attain the aim of this study.

8. References

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