Impact of Wood-based Panels Industry on the Environment

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Abstract

In the last few years the production of wood panels and in special of MDF, PB and OSB went worldwide through a dramatic growth period. The rapid increasing production capacities forced a dynamic mechanization and automation of this industrial sector. The environmental aspects of this development have just recently become in the focus of public interest due to increasing environmental requirements. Especially the waste air regulation in Central European countries required the conception of new treatment plant, which established a new state of the art in the environmental technology. For MDF factories it was possible to combine the advantages of known technologies for waste air and water and to develop them further firstly to a pilot plant and later to the state of the art. This new system completely closed all water cycles of the production site and minimized the exhaust of air pollutants. During more than five years operation this system clearly proved its economical and technical advantages. The development of this treatment plant prevailed new experiences and know-how, which are very helpful for the design and optimization of new equipment generation for reducing the environmental impact of the wood based panels industry.

Keywords: Wood based panels, MDF, waste water, waste air, environmental impact

Introduction

In the last decade the production of wood panels and in special of MDF (Medium Density Fiberboard), PB (Particleboard) and OSB (Oriented Strand Boards) went worldwide through a dramatic growth (over 50% at 230 mill.m^3/year) period. The rapid increasing production capacities and the so caused tougher competition in the market forced a dynamic mechanization and automation of this industrial sector. Modern production lines are able to produce depending on board type: 1.200 m^3 MDF, 1.600 m^3 OSB and 2.000 m^3 PB per day in average. The environmental aspects of this development have just recently become in the focus of industrial interest due to increasing environmental requirements by the officials.

Especially for the MDF production due to their specifics, i.e. squeezed water from chips and direct drying of wet glued fibre, the environmental technique is still a relatively new topic, which has to deal meanly with the treatment of waste water (similar to TMP waste water) and waste air (VOC =volatile organic compounds and dust).

For the conception of the last generation of MDF plants [Portenkirchner et al.] the goal was rather to combine the advantages of known technology and to develop them further. The new generation of equipment should completely close all water cycles of the production site and minimize of the exhaust of air pollutants. Moreover the new technology should be as simple and economical as possible.

Methods and Equipment description

Waste water ingredients
The waste water of modern MDF plants (average 350 m^3/d, last generation 500 m^3/d) is originated by squeezing out water from the warm water washed and steam pretreated wood chips. Characteristic for this waste water is the high, oscillating organic load (Tab. 1) with a normal COD (chemical oxygen demand) of 7.000 mg/l. The extraction of organic acids from the (soft) wood makes the waste water acid (pH = 5,5). The nitrogen load is on contrary to the phosphorus load too low to support a biocenosis adequately. The solid matter of this waste water is about 3 g/l and contents mostly fine wood particles [Thompson et al.].

Exhaust air ingredients
The drying of steamed, wet, resinated wood fibers (m.c.>100%), results in high quantities of waste air (average 500.000 m^3/h, last generation 700.000 m^3/h), with highly oscillating concentrations of solid and gaseous pollutants. The emitted dust contents 45% wood dust and wood fibers and 55% inorganic flue ash from the biomass energy plant because of direct heating of dryer. The gaseous pollutants are mainly pyrolysis products (i.e. formaldehyde, carbon acids, ...) and partly vaporized volatile wood chemical components (i.e. terpene, ...).

Treatment plant description

The concept of the plant [Portenkirchner et al.] can be seen in Figure 1. The key ideas of a modern waste air / water treatment plant have been:

- Grouping the waste air and waste water treatment plant by combining the water cycles in an aerobic, thermophilic activated sludge process
- Closure of all water cycles by combining a biological cleaning stage with a reverse osmosis and usage of the permeat for process steam generation
- Combination of various waste air cleaning systems for the elimination of gaseous pollutants (scrubber) and aerosols (wet electrostatic precipitator)

Moreover the activated sludge suspension is also used as washing water for the scrubber, where it is directly injected into the waste air flow. The washed out gaseous pollutants are then biologically degraded in the activated sludge tank. Therefore the temperature of the activated sludge regulates itself approximately to the adiabatic saturation temperature of the waste air, in this case 45 – 60°C, which is quite high for a biological cleaning system.

All **waste water flows** of the plant are collected in a central tank. From there the excess waste water is transported over a bow screen and a clarifier (separation of the wood particles) into an activated sludge tank. In this aerated tank (dissolved oxygen, DO = 1 – 2,5 mg/l) an adapted, aerobic biology settles. The system is specialized on the degradation of organic components without a sludge recycling. The elimination of nitrogen or phosphor has never been an aim, because of the anyhow short nutrient offer in the waste water.

Generally the **waste air treatment plant** consists of three stages:

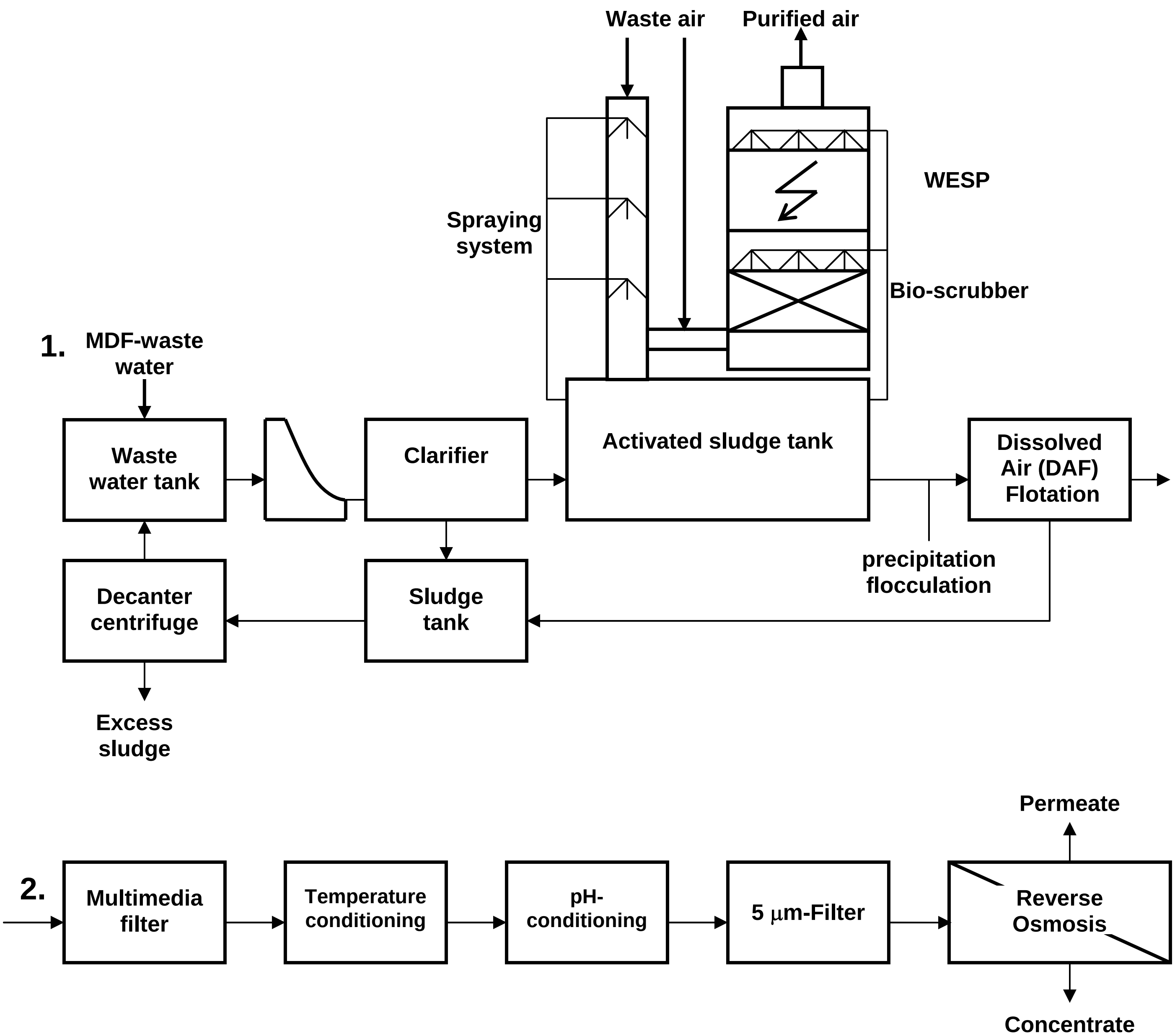
- Spraying system (rough dust and formaldehyde removal, air cooling)

-Bioscrubber (formaldehyde removal)
-Wet electrostatic precipitator (dust and aerosol removal)

Figure 1: Combined waste water and waste air treatment plant [Portenkirchner et al.]

The activated sludge suspension is also used for the cleaning of the bio-scrubber and the wet electrostatic precipitator.

After the biological treatment the waste water quality does still not satisfy the requirements for the feed water of a reverse osmosis. To reach stable condition for



reverse osmosis operation following further cleaning and conditioning stages were implemented:

- Chemical precipitation and flocculation
- Dissolved Air Flotation
- Multi media filtration
- pH-adjustment and antiscalent dosage
- 5 µm-filtration

The three stage reverse osmosis is designed for a permeate gain of 90%, a maximal pressure of 30 bar (i.e. feed water flow of 30 m^3/h). To increase the flux over the membranes, every stage has its own cycle pump. The membranes are a special development optimized for retaining organic components with a low tendency for blockages.

The sludge from the clarifier and the flotation are jointly collected in a stirred tank. From there the suspension is dewatered by a decanter centrifuge. The concentrate of the decanter centrifuge can be recycled into the raw water or into the activated sludge tank.

Measurements

The control parameters $N\text{-}NH_4$ and $P\text{-}pPO_4$ are fotometric analyzed with Nanocolor tests after filtering the sample at 0,45 µm, while the COD is analyzed with the same method but unfiltered (except the activated sludge, which was filtered).

The formaldehyde concentration in the filtered water samples (0,45 µm) was analyzed colorimetric using a Merck test.

The mixed liquor volatile suspended solids (MLVSS) and the settleable matter (SM) were measured in compliance with German Standard Methods (DIN 38414, DEV).

The pH (at 40°C) was measured electrochemical with a WTW pH340 unit, the dissolved oxygen (DO) with an Oxi197-S unit and the conductivity (at 40°C) with a WTW LF 197-S unit.

All the measurement units were calibrated on a weekly basis. Double measurements on random samples over a period of several months pointed out an analysis reproducibility of ± 10%.

The concentration of formaldehyde was measured in compliance with German Standards (VDI 3862/2), organic acids (formic acid, acetic acid) with Austrian Standards (ÖNORM EN ISO 10304-1/2), dust with Austrian Standards (ÖNORM M5861) and organic C with German Standards (VDI 3481/1).

At the autopsy of the membranes the modules, which uncovered the individual membranes, were opened. Then the blockage of the membranes was analyzed chemically, microbiologically and optically.

Results

The described full scale waste water and waste air treatment plant has been in continuous operation since the beginning of the year 2000 and has clearly proven its practical suitability in this period. Because of its innovative concept a lot of new aspects were found out, which will be further described generally.

Aerobic, thermophilic biology

At the beginning the biology was started up with a mixture of activated sludge from a communal waste water treatment plant and compost. Then it was adapted to the higher temperatures (45 – 60°C) and formaldehyde concentrations in the treatment plant over weeks.

The so selected population, which was dominated by actinomycetes, gram-positive bacteria and yeast, managed to survive immediately after the start up of the production plant. The direct injection of the activated sludge suspension into the hot waste air of the fiber dryer (up to 120°C) showed no negative effects on the activated sludge. Most outstanding was the capability of the biocenosis to regulate its living conditions without need of external chemical dosage. The pH of the activated sludge tank i.e. was strictly neutral (7 ± 0,2) although the waste water was quite acid. The constant biological degradation of the formaldehyde kept its level right beneath 1 mg/l (Tab. 1) and so on an uncritical level concerning its toxicity.

The COD degradation over the biological cleaning stage of the plant was quite stable at a level of 60%, so that the concentration in the water of the activated sludge tank was in the middle 3000 mg/l. The degraded organic substances caused only little biomass growth (0,29 g biomass growth/g COD-degradation). Although the plant operated with no sludge recycling the MLVSS in the activated sludge tank reached 1 – 2 g/l at a specific waste water flow of 0,35 d^{-1}. The sludge contented of approx. 2/3 biomass and 1/3 dust and wood particles.

Table 1: Control parameters of the waste water treatment plant [Portenkirchner et al.]

Parameter	Waste water	Output Biology	Output Flotation	Permeate
COD [mg/l]	7000	3000	1000	30
HCHO [mg/l]	< 1	< 1	< 1	< 1
$N-NH_4$ [mg/l]	2	8	6	n.n.
$P-PO_4$ [mg/l]	22	16	10	n.n.
Conductivity [µS/cm]	1400	2400	2800	250
pH	5,5	6,9	4,5	4,5

The input of phosphor over the waste water was sufficient for the support of the biology. The nitrogen support was dominated by the wash out of ammonia from the waste air. Although this ammonia input varied a lot over the time, it could sufficiently support the activated sludge and no continuos nutrient dosage was necessary. As expected before the high water temperatures in the activated sludge tank (mostly over 50°C) prevented a constant nitrification [Grunditz et al.].

The major difficulty of the biological cleaning stage was the varying and generally bad sedimentation tendency of the activated sludge [Andreasen et al.]. This and the high bulking and foaming tendencies of the sludge caused major operation problems, which forced to change the sludge separation from sedimentation to flotation. Moreover the integrity of the sludge flocs had to be supported with the dosage of flocculation chemicals. Generally aerobic thermophilic activated sludge processes for waste water from wood processing seem to have a tendency of poor sedimentation [Clauss et al.]. This must be kept in mind during the design of such plants.

Another problem was the dynamic and discontinuous foam generation in the activated sludge tank, but could be solved by dosing anti-foaming agent continuously.

Waste air treatment
The solid and the gaseous pollutants from the fiber dryer were hold back in different parts of the compact waste air treatment plant.

The cleaning of formaldehyde in two stages (spraying system, bio scrubber) allowed a formaldehyde reduction of 80% (Tab. 2). The washed out formaldehyde was then degraded by the aerobic, thermophilic biology. The stability of this process kept the concentration of this component beneath a critical value. The other pyrolysis products as formic acid and acetate acid were also reduced from the waste air by a level of 95%.

The last waste air cleaning stage was a wet electrostatic precipitator, which retained 90 % of the emitted dust. As a side effect the solvation of the washed out dust particles (flue ash from the combustion of bark/wood waste in the energy plant) increased the salt load in the waste water more than 70%. Moreover the colloidal load in the water reached a level, which required a chemical precipitation in the pre-cleaning stages of the following reverse osmosis.

Table 2: Control parameters of the waste air treatment plant [Portenkirchner et al.]

Parameter	Purified air [mg/m³]	Degradation [%]
Formaldehyde	5	82 %
Dust	3	91 %
Organic acids	0,9	97 %
Organic C	15	65 %
Blue haze	Not visible	

The fact that a lot of fibrous, sticky and hardly water dissolvable components were washed into the water system by this plant increases the risk of system blockages. But the operational experience in this full scale plant proofed that this shortcoming can be handled if this circumstances are considered in the plant design.

Waste water reverse osmosis

The operation of a reverse osmosis with waste water of such composition went despite of a optimized pre-cleaning to the technical limits of such equipment. Nevertheless a combination of biological cleaning and a membrane system had been chosen for this plant, because only the reverse osmosis could guarantee a sufficient water quality for a complete closure of the water cycles. A reference application for even tougher requirements was known at that time [Finnemore et al.].

Generally, the full scale plant verified this design issue, but being a pilot plant the development of stable operation needed surpassing exposure of finance, time and technique. During the optimization the unstable pre-cleaning stages and the sensitiveness of the reverse osmosis required a high qualification of the operation stuff. After some years of operation automation has been increased and the waste water process required no extensive supervision anymore.

For the reverse osmosis the quality of the pre-cleaning had overtop significance. Through optimization a clear, lightly yellow and solid free water for feeding the reverse osmosis could be achieved with the pre-cleaning. With an optimized combination of flocculation and precipitation the COD in the waste water could be reduced to a level of 1000 mg/l (Tab. 1). This COD-reduction based mostly on the separation of colloids with a high water fouling potential for the membrane.

The continuous stabilization of the pH at a level beneath 5,5 avoided iron and manganese fouling on the membrane despite their very high concentration in the waste water. Due to the fact that the water in the biological cleaning stage was strictly neutral the pH had to be reduced continuously, which could normally be done by the use of acid precipitation chemical without an extra dosage of inorganic acids.

As a result of the complex pre-cleaning the reverse osmosis could deliver permeate at a gain of 90%, which fulfilled the water requirements for an open process steam generation system at 12 bar (Tab. 1). The concentrate could be used as feed up water for the glue preparation. This makes it possible to run the whole MDF plant waste water free.

Despite all that emphasis on the operation of the pre-cleaning system, blockages of the membranes still occurred, which made the development of discontinuous cleaning programs with special chemicals necessary. Using this cleaning operations most of the membrane blockages could be removed. For this reason the performance of the reverse osmosis deteriorated consequently, which so far limited the lifetime of the membranes to two years and influenced the operational costs.

To check the circumstances of this deterioration a membrane autopsy was done, which showed heavy bio-fouling caused by the high amount of organic matter and the huge number of organisms in the feed water of the osmosis. To a certain extent also flocculation chemicals and waste water colloids caused also a part of the blockages. These substances were transported to the membranes during operational problems in the pre-cleaning (over dosage of flocculation chemicals, poor cleaning efficiency). Inorganic facings from scaling processes played a minor role. Also no mechanical, thermal or chemical degradation of the membranes itself could be found.

Practical Relevance

In this waste air – water treatment plant several complete new process approaches had been developed at an industrial scale and combined in a very complex way. The years of operation clearly proofed the pilot plant practical capability.

The unique combination of waste water and waste air cleaning, the combination of a biocenoses with a reverse osmosis and the use of an aerobic, thermophile organisms has not only set a new state of the art, but also offered interesting experience for further research projects. Moreover the treatment plant concept can be adapted to various similar applications in other industrial sectors.

The membrane lifetime and its sensibility were so far seen as the major problems in the reverse osmosis technology in MDF waste water applications. However the technology has proven to deliver suitable water quality to feed process steam generators and to close the water cycle in the MDF production. Moreover the design of the pre-treatment and the design of the reverse osmoses itself offer enough potential to improve membrane lifetime and reliability significantly. Considering this and taking the ever increasing energy cost into account reverse osmosis process is again a promising alternative to the far more energy consuming waste water vaporisation technology.

Acknowledgements

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