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A METHODOLOGY AND PROCESSES FOR ASSESSMENT OF THE COMPLIANCE OF EXISTING WOOD-BASED PANEL PRODUCTION PLANTS WITH BAT REQUIREMENTS

All producers of wood-based materials should know to what extent their facility is in compliance with BAT (Best Available Techniques) requirements (Reference Document for the Production of Wood-based Panels, 2016). This paper presents a methodology with optimized procedures to evaluate the compliance of a facility with BAT requirements, verified using the example of an existing wood-based panel production plant. Model production of particleboard consumes 500,000 tonnes of wood (actual weight – LUTRO) annually; the largest shares are those of coniferous pulpwood with nearly 150,000 tonnes, sawdust with around 110,000 tonnes, and others. Approximately 400,000 m^3 of raw particleboard is produced per year, of which about half is laminated. The company manufactures annually almost 22 million m^2 of impregnated foil. There are 34 points at the plant where air emissions occur. During particleboard production, 27 types of hazardous waste and nine kinds of other waste are generated. The article is a brief overview of the subject matter and the results of research. The methodology comprises a set of theoretical analyses, results of controls on site, analyses and measurements, which are processed in 16 steps. In this article, we report the results of comparisons of the parameters of the monitored plant with the parameters of the best available technology. In the processes of production, drying and shredding of chips, the critical locations, or most demanding in terms of meeting the BAT requirements, are sawdust storage or sawdust handling, and the chip dryer. The drying of chips is the main source of air pollution and a potential source of odour. A wet electrostatic precipitator was implemented to minimize emissions from the dryer. Authorized emission measurement indicates an average PM value of 3.57 mg/m^3 (with 17% O_2), against a current emission limit of 20 mg/m^3. The result of authorized measurement of TOC is 49 mg/m^3, while the current emission limit is 300 mg/m^3. The real values of the formaldehyde concentration measurements are low, below 0.76 mg/m^3. The current emission limit for the sum of concentrations of formaldehyde, acetaldehyde, phenol and formic acid is 25 mg/m^3. Thorough environmental management analysis of the compliance of the existing particleboard production plant has a positive impact on several

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environmental and economic solutions. Moreover, a series of measures and communication with competent environmental protection authorities are proposed.

Keywords: particleboard production, IPPC, BAT requirements, assessment, environmental management

Introduction

Research in the area of production of wood-based materials is concentrated particularly on expanding non-traditional raw materials based on biomass [Lykidis et al. 2014; Gűler et al. 2016; Wang et al. 2016; Klímek et al. 2017] and on new types of adhesives [Moubarik et al. 2013; Paiva et al. 2014; Esteves et al. 2015]. Large-capacity production of wood-based materials is subject to ever stricter requirements in terms of environmental protection and optimal use of raw materials [Directive 2010/75/EU 2010; Saravia-Cortez et al. 2013; Garcia and Freire 2014; Kim and Song 2014]. Emission limits are becoming stricter and effective solutions are required for reducing fugitive emissions and odours. There is constant interest in the issue of formaldehyde emissions from wood materials and their production [Frąckowiak et al. 2014; Akyüz et al. 2017]. Research is being carried out with a focus on the production and lifecycle of particleboards [Silva et al. 2014; Iritani et al. 2015; Nakano et al. 2017]. Energy optimization of this production process is also very important [Knauf 2015].

In recent years the greatest innovative changes have been made by manufacturers of wood products, mainly producers of wood-based panels [Szostak and Ratajczak 2009]. It is now necessary to for these activities to be synchronized with the new requirements of the IPPC Directive and EIA.

Act no. 39/2013 of the Slovak Republic on integrated pollution prevention and control (IPPC) incorporated Directive 2010/75/EU of the European parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) into the Slovak legal system [Act no. 39/2013 SR] and EIA [Act no. 24/2006 SR]. All producers of wood-based materials with threshold capacity > 600 m^3/day ought to be aware to what extent their facility is in compliance with Best Available Techniques (BAT) requirements. In Slovakia there are two producers of particleboard with a production capacity exceeding this threshold.

It was necessary to create a methodology to assess the compliance of the sites with the requirements of the reference document for wood-based material production [Stubdrup et al. 2016] and the conclusions of BAT [2015] "BAT Reference Document for the Production of Wood-based Panels" and to implement it in actual operations. This is the principal aim of our article. A subsidiary goal is to propose further technical and environmental management techniques to increase the environmental quality of particleboard production.

Research methodology

The methodology consists of a set of theoretical analyses, results of controls on site, and analyses and measurements:

1st Step Detailed analysis of current state of production of particleboard and related operations – material and energy balance.
2nd Step Identification of critical points in terms of possible environmental impacts.
3rd Step Introduction or internal control of environmental management system.
4th Step Preparation of environmental impact reports.
5th Step Preparation of baseline report before starting operation of an installation or before a permit for an installation, to document the current state of contamination of soil and groundwater.
6th Step Measurement of concentration and mass flows of pollutants in all chimneys and air outlets.
7th Step Measurement or expert estimates of fugitive emissions.
8th Step Production of an emission study based on results of measurements.
9th Step Production of emission studies of diffuse emissions.
10th Step Preparation of technical and organizational measures to protect the environment.
11th Step Measurement of concentrations and mass flows of pollutants released into water courses.
12th Step Preparation of a study of water pollution.
13th Step Preparation of a noise study.
14th Step Measurements relating to hygiene of the working environment.
15th Step Preparation of a health study.
16th Step Preparation of an application for a permit to implement IPPC in accordance with Act 39/2013 of the Slovak Republic on IPPC.

Generally, for the preliminary study, technical measurements will be sufficient. Only authorized measurements by accredited measuring groups are permitted for official procedures involving the atmospheric protection authorities. For the measurement of emissions, first of all EN standards, or in their absence ISO standards or national standards, are used. Similarly, authorized measurements are required by the water protection authorities and for other purposes. Individual studies are prepared by competent persons entered in the registers of the Ministry of the Environment, the Ministry of Transport or the Ministry of Health.

All of this documentation is sufficient for the requirements of Directive 2010/75/EU to be fully addressed, particularly Articles 11-13, and for the competent authorities to process the permit conditions (Article 14).

Brief description of particleboard production operations

The technical process of production of raw particleboards begins with storing of the input raw materials, and continues with the production, drying and sorting of chips, and storing of dried, sorted particles, with transport between operations performed mechanically and using air. This is followed by the preparation of adhesive mixtures, and application of adhesive mixtures and other chemicals to the chips. In the main production hall, operations are performed on the shaping line, press, finishing line, intermediate store, grinding line, formatting line and packing line. Operations include the surface treatment of the raw particleboard by lamination, for which laminated paper – paper impregnated with special bitumen resin – is prepared at the facility.

Particleboard production consumes 500,000 tonnes of wood (actual weight – LUTRO) annually, the largest shares being those of coniferous pulpwood with nearly 150,000 tonnes, sawdust with around 110,000 tonnes, and then cuttings, chips, and hardwood and softwood fibres. In addition, there are almost 40 types of adhesives, auxiliary materials and other substances, each type with an annual consumption of at least 1 tonne. Approximately 400,000 m^3 of raw particleboard is produced per year, of which about one half is laminated. The company manufactures annually almost 22 million m^2 of impregnated foils.

Use of fuel and electrical energy is as follows:

- Motor diesel 290,000 l per year;
- Natural gas for the chip dryer – max. gas consumption 5000 m^3/h;
- Wood energy recovered in the dryer – max. consumption of wood dust 7500 kg/h, average consumption 4100 kg/h;
- Heat purchased (for production of impregnated paper, bonded boards and heating) – max. heat consumption 12 GJ/h, average daily consumption ca. 140 GJ/day.

Almost 10,000 m^3 of drinking water and more than 90,000 m^3 of utility water is consumed per year.

There are 34 points at the plant where air emissions occur, and all locations have been officially measured by an authorized measuring group. Wastewater is cleaned by means of a mechanical-biological wastewater treatment system.

In producing particleboards, 27 types of hazardous waste and nine kinds of other waste are generated. The total amount of waste produced is more than 900 tonnes per year, of which hazardous waste represents up to 315 tonnes per year. Removal of hazardous waste is provided by an authorized external company.

Results and discussion

Identification of critical locations regarding possible impacts on the environment

In the process of production, drying and chipping, there are two critical locations – the sawdust store, or sawdust handling generally, and the chip dryer. Similar to the sawdust store, the chip store is located in the open, but given the dimensions and humidity, chip storage is not a source of particulate matter surface emissions. The other equipment is in closed halls or otherwise covered to avoid the creation of other sources of air pollution. Dried chips are stored in a concrete silo. The drying of chips is the main source of air pollution and a potential source of odour.

Under Article 22 paragraph 2 of Directive 2010/75/EU of the European Parliament and Council, "Where the activity involves the use, production or release of relevant hazardous substances and having regard to the possibility of soil and groundwater contamination at the site of the installation, the operator shall prepare and submit to the competent authority a baseline report before starting operation of an installation or before a permit for an installation." The baseline report should contain the information necessary to determine the state of soil and groundwater contamination so as to make a quantified comparison with the state upon definitive cessation of activities provided for under paragraph 3.

The baseline report should contain at least the following information:

(a) information on the present use and, where available, on past uses of the site;
(b) where available, existing information on soil and groundwater measurements that reflect the state at the time the report is drawn up or, alternatively, new soil and groundwater measurements having regard to the possibility of soil and groundwater contamination by those hazardous substances to be used, produced or released by the installation concerned.

For the purposes of preparing a baseline report, a geological survey was carried out. The geological survey was performed in accordance with Act no. 569/2007 on geological works, taking into account the possibilities of taking samples from built industrial land (buildings, roads, sewers, utilities, etc.). Samples were taken and analysis performed on soil, and ground water was also sampled.

The results of analysis of groundwater showed that the water is not contaminated and no active measures are needed for remediation. The concentration of phenols is max. 12 µg/l, the concentration of crude oil substances (NEL-IR) is max. 70 µg/l, the concentration of ammoniacal nitrogen is max. 40 µg/l, and the concentration of formaldehyde is around 50 µg/l.

The soil has a neutral to slightly alkaline pH, but does not show signs of ammonia contamination, the formaldehyde concentration is low and the content of phenolic compounds is negligible.

Results of analyses, authorized measurements and evaluation of compliance with BAT requirements

Comparisons of the parameters of the monitored plant with the parameters of the best available technology are summarized in table 1.

Table 1. Comparison of the parameters of the monitored plant with the parameters of the best available technology

Monitored area	BAT requirements	Applied solutions and remarks
Results of measurement stated	As half-hour or daily averages	In compliance
Waste gas from dryer furnace	Equivalent for dry gas and 11% reference oxygen	Not applicable in this case. The combustion chamber is integrated into the dryer without the possibility of sampling between the furnace outlet and the inlet to the dryer
Waste gas from wood particle dryer	Equivalent for wet gas and 18.5% reference oxygen	In compliance. Currently for Slovakia stricter conditions are in force, with the equivalent for wet gas and 17% reference oxygen
Waste gas from other processes	Based on operating conditions	In compliance
Wood particle dryer	Wet electro-static precipitator (WESP) from the dryer to minimize emissions. Original quotation from BREF: "WESPs are useful for reducing wood-dust, fine dust (aerosols) and odour in dryer emissions and also press emissions, where the emissions have been cooled and wetted down to a temperature close to the dew point of the particulates. Also, formaldehyde and other organic compounds expressed as TOC are reduced, to a certain degree"	Implemented
	Concentration of particulate matter 3-40 mg/m^3 (when using WESP concentration should be around the lower boundary)	In compliance. Authorized emission measurement – average value 3.57 mg/m^3 (with 17% O_2). The current emission limit is 20 mg/m^3
	Concentration of TOC 5–100 mg/m^3 (for raw materials with a high natural content of terpenes concentrations are at the upper boundary)	In compliance. The raw material is mostly coniferous with a high content of terpenes. Results of authorized measurements are 49 mg/m^3. The current emission limit is 300 mg/m^3

Monitored area	BAT requirements	Applied solutions and remarks
	Emission factor of formaldehyde 0.2–0.5 kg/m^3 of boards produced	Under the laws on air protection in Slovakia, concentrations are measured, not emission factors. The real values of the concentration measurements are low, below 0.76 mg/m^3 The calculated emission factor is around 0.35 kg/m^3 of boards produced. The current emission limit for the sum of concentrations of formaldehyde, acetaldehyde, phenol and formic acid is 25 mg/m^3
	Concentration of NO_x 120-300 mg/m^3 (for directly heated dryers)	In compliance. Combustion process optimized with respect to the assessment of nitrogen oxide formation [Rimár et al. 2016]. Authorized emissions measurement at the lower boundary of 145 mg/m^3. The WESP is found to cause a moderate increase in the concentration of nitrogen oxides, since the real value when the WESP was switched off was 63 mg/m^3. The current emission limit is 650 mg/m^3
	Concentration of CO not stated in BREF	In accordance with the national emission limit – the current emission limit is 250 mg/m^3
	Partial recirculation of waste gas from the dryer to the mixing chamber	Implemented.
Waste gas from mechanical processing and transport of disintegrated wood material and formatting of mat	Application of efficient particulate matter emission separators (fabric filters, high performance cyclones, cyclofilters)	In accordance with requirements – in all cases of separation of dry wood particles, BAT-compliant material filters are used
	Concentration of particulate matter 2-5 mg/m^3	Real values 0.4-2.8 mg/m^3, in the case of a single air outlet the concentration is 5.56 mg/m^3. The current emission limit is 50 mg/m^3; in the case of grinding boards the emission limit is 10 mg/m^3
Emissions from the press	Based on operating conditions. Concentration of particulate matter 3-10 mg/m^3	Not applicable in this case – waste gas from the press is not discharged into the atmosphere but is introduced into the absorber and then into the chimney stack. The same applies to TOC and formaldehyde
Emissions from impregnation of paper	Use of low-formaldehyde resin	Resins with low content of formaldehyde are used, ensuring the highest emission quality (E1) for laminated particleboard products
	Concentration of formaldehyde from adhesive production is not stated in BREF	Compliant with the national emission limit – the current limit is 20 mg/m^3

Monitored area	BAT requirements	Applied solutions and remarks
	Emissions of TOC from the paper impregnating line without cleaning of waste gas but with use of a resin with low content of VOC, up to 50 mg/m^3, to ensure a TOC concentration in waste gas of 10-30 mg/m^3	Solvent-free resins are used, therefore effective cleaning to provide a TOC concentration of 10-30 mg/m^3 is not required. Authorized emission measurements from five air outlets 0.5-2.8 mg/m^3; at one outlet there was an average value of 6.77 mg/m^3. No specific national emission limit is defined
	Effective cleaning to achieve a concentration of formaldehyde ≤5 mg/m^3	The choice of resin means cleaning is not necessary. This condition is fulfilled, as is the current emission limit of 20 mg/m^3
Fugitive emissions	Effective ventilation of the room containing the press	Implementation of a working environment in accordance with health requirements
	Regular cleaning of roads and spaces for storing disintegrated material and means of transport	In accordance with requirements. Managed under the operating rules
	Unloading of sawdust in specially closed drive-through areas with closed doors. *Original Requirement* – Unloading of sawdust using covered drive-through unloading areas with closed doors	Unloading sawdust in a closed area is not possible for safety reasons, because air with wood dust is highly explosive. Substitute measures implemented – in case of windy weather, spraying with water. We performed operational measurements of ultra-fine particles (10–100 nm) and microparticles (0.1–10 μm) in close proximity to the unloading of sawdust (fig. 1) and in the open space of the site. The results showed that unloading of sawdust is not a source of excessive dustiness
	Storage of dusty materials in silos	Dried disintegrated wood is stored in silos
	Minimization of dust emissions during dry and windy weather by sprinkling open stocks of dusty materials	Applied. The humidification procedure is performed according to the established operating rules
Emissions into water	Separately collect and treat water from areas where wood raw materials are stored. Separately collect and dispose of rainwater from the roofs	Relatively small production of such water. Drainage water from roofs and paved surfaces is discharged into a receiver in accordance with the requirements of the competent authority. The water meets the requirement for discharge into the receiver
	Remove point sources of pollution of water e.g. installation of roofs over production areas	Fulfilled. All possible production areas are in halls or covered
	Paved surfaces for storing logs, raw materials to reduce the load on cleaning water	Fulfilled. All storage areas have a concrete or asphalt base
Water treatment from wet cleaning of waste gas	Apply sedimentation, decanting or another method of thickening to remove solid materials from the system of wet cleaning of gases	Implemented by the WESP

Monitored area	BAT requirements	Applied solutions and remarks
Results from measuring emissions into water	As daily proportional averages	In accordance with legal requirements on measurements
Do not exceed the concentration in the overall collected surface water released into the receiver	Non-soluble materials 10-40 mg/l	Condition fulfilled
	COD 20-150 mg/l	Condition fulfilled
Emissions into soil and groundwater		
Handling resins and additives	Only in defined areas with protection against leakage	Fulfilled – in production areas
Storing the stated materials	Protected against leakage	Fulfilled – in production areas
Leakage of materials	Technical solution for capture	Building technical solution – capture baths and insulated floor
Energy efficiency	Optimize the operation of combustion equipment by monitoring the process and checking the key parameters of the combustion process	All energy equipment is managed and controlled to achieve the highest possible efficiency
	Drain fuels from biomass and sludge	In accordance with the requirement – for energy purposes, dry wood dust is used. Sludge is not incinerated
	Take advantage of the waste heat of hot gases from wet scrubbing. Recirculate hot gases from different processes to the dryer	In view of the very humid environment, recuperation would be ineffective, or technologically very problematic
Waste	Reuse own waste wood in production or to produce heat	A process to do this is designed and implemented – no biomass is taken out of the works as waste
Combustion products	Continuously seek possibilities for recovery	Ash taken out by an authorized organization which thus far does not have proper recovery options. Here, further research is being done to recover this type of ash from the flue gas of the wood chip dryer
	Efficient system of combustion which minimizes the amount of remnants from combustion	Fulfilled. Optimally managed process of burning wood particles in the incinerating furnace of the dryer
	Safe handling of ash and its transport and storage. In the preventive humidification of the ash, use a secondary water source	Approved system of the authorized organization
Noise	Individually seek effective measures to reduce noise and prevent transmission of noise from source to receiver	Research is performed periodically to detect sources of noise and to insulate sources of noise [Ladomerský et al. 2010]

Fig. 1. Emptying of wood chips out of trucks

Proposed measures

To avoid emissions – or if that is impossible, then to limit emissions (gaseous, liquid and solid) – a list was drawn up of selected technical and organizational measures for air, water and waste management to reduce emissions (gaseous, liquid and solid).

Emissions from the production of particleboard are measured periodically in accordance with the decisions of the relevant government environment office. For each calendar year, an emission statement is issued and sent to NEIS. To prevent the generation of waste, or to increase the proportion of waste recovered, the production company has adopted an internal directive on the separation of selected components of waste.

In the long-term strategy to improve the running of particleboard production and related operations, and in the final phase of preparation for IPPC implementation, all technically feasible and organizational measures were taken to minimize its negative impacts on the quality of life of residents of the nearby estate and the environment in general.

A wide range of other measures to minimize emissions to all elements of the environment has been proposed. An emergency operating plan has been developed. Once every two to three years, there will be a comprehensive assessment of the possibility of implementing further measures.

Conclusions

In this article, a methodology for assessment of the compliance of a particleboard production plant with BAT (Reference Document for the Production of Wood-based Panels) requirements has been described and proven in real operations. The entire process of verifying compliance of operations with

BAT requirements includes 16 steps, and is somewhat lengthy. This procedure will ensure consistent compliance with the requirements of Directive 2010/75/EU, in particular Articles 11–13, and that the competent authority is able to process the permit conditions (Article 14).

In the processes of production, drying and shredding of chips, two locations are critical, or most demanding in terms of meeting the BAT requirements – sawdust storage or sawdust handling, and the chip dryer. The assessed operation meets all requirements, often with a large margin relative to emission limits. Authorized emission measurements indicate an average PM value of 3.57 mg/m^3 (with 17% O_2), compared with the current emission limit of 20 mg/m^3. Results of authorized measurements of TOC are 49 mg/m^3, the current emission limit being 300 mg/m^3. The real values of the formaldehyde concentration measurements are low, below 0.76 mg/m^3. The current emission limit for the sum of concentrations of formaldehyde, acetaldehyde, phenol and formic acid is 25 mg/m^3.

As a point of interest, we note that in the authorized measurement of emissions it was shown that the wet electro-filter moderately increased the concentration of NO_x.

A wide range of further measures were proposed to minimize emissions into all elements of the environment, in line with the long-term goal of the environmental management system to continuously improve the operation of particleboard production and related operations.

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