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Evaluation of occupational exposure to wood dust among sawmill workers within the Gert Sibande District Municipality, South Africa

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Abstract

Introduction and Objective. Wood dust is regarded as one of the human carcinogen based on an increased risk of nasal and sinonasal cancer. This study was conducted in two sawmills to measure and determine the time-weighted average (TWA) exposure level to wood dust, and compare the results with the South African occupational exposure limit (OEL).
Materials and method. Personal and area respirable and total inhalable wood dust samples were collected using calibrated Giliair-3 personal air sampling pump (Sensidyne, USA). Data was analysed using Microsoft Office Excel 2019 Analysis Tool Pak for a summary of descriptive statistics. Both the geometric means and standard deviation as well as the minimum and maximum values were calculated.
Results. The geometric mean = GM (geometric standard deviation = GSD) for personal respirable wood dust exposure at sawmill A was 0.9(4.8) mg/m^3 while at sawmill B – 0.57(0.75) mg/m^3. The GM(GSD) for personal total inhalable wood dust exposure at sawmill A was 0.37(0.94) mg/m^3 while at sawmill B – 1.19(16.91) mg/m^3. Besides that, the GM(GSD) for area respirable wood dust at sawmill A was 0.13(0.09) mg/m^3, while at sawmill B – 0.8(0.6) mg/m^3. Likewise, the GM(GSD) for area total inhalable wood dust at sawmill A was 0.13(0.16) mg/m^3 while at sawmill B – 0.54(0.55) mg/m^3.
Conclusions. Results for the majority of samples were below the OEL. Workers smoking tobacco or cigarettes should be encouraged to stop smoking since smoking, especially when associated with exposure to wood dust, may increase the risk of respiratory health symptoms

Key words
Wood dust, occupational exposure, human carcinogen

INTRODUCTION

Wood is the most important renewable natural resource, and the Global Environmental Fund emphasises that about 700 million cubic metres of wood are harvested each year for industrial purposes [1, 2]. Nearly 69% of the wood utilised worldwide belongs to the softwood group while 58% of wood used as a fuel belongs to the hardwood [3, 4]. The utilisation of wood by different wood-related industries vary among countries, regions and type of wood products [5]. Wood is processed for a wide variety of uses. The composition and substance which may affect its properties are described in detail elsewhere [5]. According to Kauppinen *et al.*, more than 3.6 million people are exposed to wood dust worldwide, and the highest exposure levels have been reported in the furniture and cabinet making industries. The effects of wood dust exposure in the furniture manufacturing industry may be enhanced by exposure to solvents and formaldehyde in glues and surface coatings [6].

Sawmill processes generates wood dust particles of different sizes, concentration and composition [7, 8, 9]. Likewise, the majority of wood dust fractions are contributed by dust particles with a diameter greater than 10 micrometer (μm) which can adhere to the nasal passage, for which the use of an inhalable mass sampling is most suitable to predict the risk of nasal cancer [10]. Inhalable dust is the fraction of a dust cloud that can be breathed into the nose or mouth, and can be deposited anywhere in the upper respiratory tract, while respirable dust (particulate matter) is the fraction of inhaled dust that can penetrate beyond the terminal bronchioles into the gaseous exchange region of the lungs [11]. Inhalable particulate matter (IPM) sampling is used for the personal monitoring of wood dust since the concentration and size distribution of wood dust may differ depending on the kind of timber and its local sources [10]. Respirable mass sampling can be used when there are health concerns for occupational asthma resulting from exposure to dust containing plicatic acid during the processing of of *Thuja plicata* (Great Western Red Ceder) timber, or from dusts containing resin acids and/or monoterpenes when processing various kinds of softwood [1, 12, 13].

Microorganisms and their products may be abundant in wood tissues and have been identified as causative agents of respiratory diseases resulting from occupational exposure to wood dust [7]. Allergens of filamentous fungi, mostly those from the genera *Aspergillus, Cryptostroma, Paecilomyces, Penicillium, Rhizopus and Trichoderm*a, have been identified as common causes of hypersensitivity pneumonitis, while (1→3)-β-D- glucans present in fungal cell wall may elicit a non-specific, inflammatory lung reaction, described as

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organic dust toxic syndrome (ODTS) [14,15,16, 17, 18, 19]. It has been demonstrated recently that Gram-negative (Gram-) bacteria and actinobacteria present in wood dust may cause hypersensitivity pneumonitis [20], whereas endotoxin (cell wall lipopolysaccharide) produced by Gram- bacteria may be a common cause of ODTS [21]. Belin and Land *et al.* carried out a study at Swedish sawmills and found that the kiln drying was contributing factor to the high mould exposure in the trimming departments [22, 23]. This finding might be accurate because it has been indicated that the air drying process, prior to kiln drying, reduces the moisture content on the timber, preventing the excessive growth of microorganisms [1].

It has been specified that exposure to endotoxins above 20 nanograms per cubic metre (ng/m^3) TLV can increase the risk for development of chronic bronchitis among those exposed to organic dust [24]. This is mainly because organic dust is contaminated by Gram-negative and Gram-positive bacteria, as well as by mould and fungi [24]. A study conducted in New South Wales, Australia, among sawmill and chip mill workers found a significant correlation between personal exposures to respirable endotoxin, glucan, inhalable glucan and fungi with chronic bronchitis [1]. However, prolonged exposure to fungi at lower concentrations can increase the risk for the development of hypersensitivity pneumonitis [1]. The implicated fungi in the development of hypersensitivity pneumonitis are mainly the dry spored species Aspergillus and Penicillum, which produce abundant spores of respirable size of less than 5 µm [1]. However, the use of highly efficient extraction systems can reduce the levels of microorganisms in the air of workplaces.

Wood dust monitoring has been carried out since 1970, even though the level of exposure may have been higher in the past due to the non-existence or less efficiency of the local exhaust ventilation, and other measures to control dust [6]. The number of woodworking machines has increased greatly since the beginning of the industrial revolution, and an increase in the demand for sawn softwood or hardwood products have resulted in companies building faster machines to increase the speed of production, resulting in finer dust particles being emitted than in the past [5]. The introduction of engineering controls by some industries since 1950 have considerably lessened exposure among workers; however, the engineering controls, even when properly adhered to, may not be 100% effective in reducing the exposure below the OEL, because the sander can generate a dust level that may be more difficult to control [5]

Sawmill workers are exposed to wood dust particles of different sizes which may cause respiratory health effects [25]. An assessment of the health effects of exposure among humans and the interpretation of the concentration of the measured results may be difficult to undertake due to the variation in the wood dust particles which differs in physical or chemical property [26]. Sampling of a known volume of air into a sampling medium is used to determine the concentration of wood dust particles in the air or workers' breathing zone to demonstrate whether the workers' exposure to inhalable or respirable dust is adequately controlled [27].

The main objective of the presented study was to determine the occupational exposure levels to wood dust among workers in the timber processing sawmills in the Gert Sibande District Municipality in Mpumalanga Province, South Africa.

MATERIALS AND METHOD

Location and sampling site. The study was conducted at two sawmills located in the Gert Sibande District Municipality in Mpumalanga Province, South Africa. The sawmills were selected based on their size, number of workers, location and type of wood processed. At the sawmill, logs are taken from the log yard to conveyor belts using type Bell machines. The rough bark is removed by a debarker,and the bark is sold or used to fuel the kilns. The logs are then sawn into boards or planks by the head rig saw, and then sorted and staked before being transported to the kilns to dry. Some adjustments are made to the dried timber which are sorted according to grades. The planks are then wrapped and packed in the warehouse for distribution.

The areas covered for total inhalable dust sampling at the sawmills comprised of the knotty pine and profile house, door house, dry mill, wet mill and saw shop. Other areas covered included the door house next to the first profile cutter, green chain next to the first chipper, knotty pine and profile house next to the first profile cutter, door house next to the first staffer machine, door house next to second profile cutter, and knotty house next to the second profile cutter. Environmental conditions did not have any influence on the monitoring results, and the equipment calibrated before and after use. The calibration status remained within calibration parameters.

Study population and selection of participants. This was a cross-sectional study conducted among sawmill workers who were classified according to their job titles, which included: chipper operator, unscramble operator, log operator, welder, stopper operator, Bell driver, profile cutter, log frame operator, general worker, trim saw operator, staffer operator, door cutter, house keeper and grader. The type of sampling strategy used was based on the random selection of 34 workers who were observed to be closer to the sources of wood dust emission and monitored for respirable and total inhalable wood dust, as per the NIOSH sampling strategy.

Sampling procedure. Personal and area respirable and total inhalable wood dust exposure were monitored using Gilair-3 personal air sampling pumps. The flow rates of the portable pumps were calibrated to 2 litres per minute (l/min) using the Gillian Gilibrator-2 (Sensidyne, U.S.A.) for total inhalable dust and 1.7l/min for respirable wood dust, according to NIOSH method [11, 28, 29, 30]. The sampling heads for the total inhalable dust were fitted with 37 mm diameter filters, 0.8 µm pore size mixed cellulose ester (MEC) filters; for respirable dust sampling, a 10 mm nylon cyclone was used. Thirty-four study subjects (16 for respirable and 18 for total inhalable wood dust exposure) as per NIOSH guideline were included in the study [31, 32, 33, 34, 35]. Before placing the instrument on the workers, the purpose of the study as well as the procedures to be followed were explained to them, after which consent forms and a hazardous chemical substance field sheet were completed.

The gilair personal air sampling pumps were attached on the exposed workers' belt with the tubing running at the back or sides. The sampling head was attached to the workers' upper chest or collar, within their breathing zone (within 30 cm from their nose or mouth), and the pump was switched on to run for a period of eight hours'. The sampling heads for area monitoring were securely attached to a stable platform at head height, as near as possible to the source of emission of airborne contaminants, and away from any obstructions to fresh air inlets. The workers who were provided with pumps were constantly monitored while performing their tasks to ensure that the equipment was operating effectively. The pumps were removed from the workers at the end of the working shift and the hazardous chemical substance field sheets were completed. The collected samples were stored in a safe place before transportation to the laboratory for analysis.

Ethical approval (Clearance No.: UFS-HSD2019/2236/3006) was obtained from the Health Science Research Ethics Committee of the Free State University. Permission to conduct the study was granted by the managers in charge of the sawmills, and the participants gave consent to take part in the study. Participation in the study was voluntary and participants were allowed to withdraw at any time.

Statistical analysis. Data was analysed using Microsoft Office Excel 2019 Analysis Tool Pack to obtain a summary of descriptive statistics. Both the geometric means and standard deviation, as well as the minimum and maximum values, were calculated. The data were not normally distributed, hence the Mann-Whitney U test was used to test the significance of the differences between the values in sawmill A and B. A significance level of 0.05 was applied.

RESULTS

The summary statistics of personal respirable and total inhalable wood dust exposure levels from sawmills A and B is shown in Table 1. A total of 16 respirable and 18 total inhalable wood dust samples were obtained at the sawmills to determine personal exposure levels to wood dust (Tab. 1). The mean or standard deviation (SD) for personal respirable wood dust results at sawmill A was 3.4(5.1) mg/m^3 with a GM(GSD) of 0.9(4.8) mg/m^3,while at sawmill B – 0.85(0.80) mg/m^3 with a GM(GSD) of 0.57(0.75) mg/m^3. The results ranged from 0.09 – 13.57 mg/m^3 at sawmill A with the median equal to 1.205 and 0.14 to 2.25 mg/m^3 at sawmill B, median equal to 0.425. The mean (SD) personal total inhalable wood dust results at sawmill A was 0.72(1.01) mg/m^3 with a GM(GSD) of 0.37(0.94) mg/m^3,while at sawmill B – 9.54(17.82) mg/m^3 with a GM(GSD) of 1.19(16.91) mg/m^3. Furthermore, the results show that the exposure levels ranged from 0.10 – 3.03 mg/m^3 at sawmill A, median equal to 0.245 mg/m^3 and 0.01 to 57.1 mg/m^3 at sawmill B, median equal to 1.84 mg/m^3. A non-significant difference was observed when the wood dust exposure levels of sawmill A and B were compared.

The summary statistics of the area of respirable and total inhalable wood dust exposure levels from sawmill A and B are shown in Table 2. Six samples for area respirable wood and 11 samples for total inhalable wood dust exposure, respectively, were obtained at the sawmills to determine the background concentration of wood dust in the workroom air. The mean (SD) value for the area of respirable wood dust level at sawmill A was 0.16(0.13) mg/m^3,with a GM (GSD) of 0.13(0.09) mg/m^3,while at sawmill B, this was 0.96(0.69) mg/m^3 with a GM (GSD) of 0.8(0.6) mg/m^3. The wood dust exposure levels ranged from 0.07 – 0.25 mg/m^3 at sawmill A, median equal to 0.16 mg/m^3, and 0.37 to 1.96 mg/m^3 at sawmill B, median equal to 0.75 mg/m^3. With regard to the area of total inhalable wood dust exposure levels, the mean (SD) value was 0.2(0.18) mg/m^3 for sawmill A, with a GM (GSD) of 0.13(0.16) mg/m^3, while at sawmill B it was 0.68(0.61) mg/m^3 with GM (GSD) of 0.54(0.55) mg/m^3. The results indicate that the area exposure levels for total inhalable dust ranged from 0.05 – 0.4 mg/m^3 at sawmill A, median equal to 0.1 and 0.29 to 1.89 mg/m^3 at sawmill B, median equal to 0.49.

The proportion of samples for personal respirable and total inhalable wood dust exposure levels below or above the action level and occupational exposure limit is shown in Table 3. The action levels refer to the concentrations of airborne hazardous chemical substances that trigger certain provisions of the regulation, but are not always, for instance, one-half (0.5) or 50% of the occupational exposure limit (OEL), while OELs are the limit values set by the Minister of Labour for hazardous chemical substances in the workplace, revised from time to time by notice in the government gazette [36, 37]. The results show that 78 and 88% of the samples for total inhalable and personal respirable dust, respectively, were below both the 2.5 mg/m^3 action level and 5 mg/m^3 OEL. Furthermore, 13% of the personal respirable wood dust samples were above both the action level and OEL, while only one sample for personal total inhalable dust was above the action level but below

Table 1. Summary statistics of personal respirable and total inhalable wood dust exposure levels from sawmill A and B

Sawmill	Wood dust type	No. of samples	GM mg/m^3	GSD	Median mg/m^3	Range	Mean (SD) mg/m^3	Min mg/m^3	Max mg/m^3	Skewness	Z-Score	p-value*
Sawmill A	Respirable	8	0.881	4.763	1.205	13.48	3.4(5.09)	0.09	13.57	1.59	0.16	0.87
Sawmill B	Respirable	8	0.570	0.75	0.425	2.11	0.85(0.75)	0.14	2.25	1.13		
Sawmill A	Total inhalable	8	0.374	0.940	0.245	2.93	0.72(1.01)	0.10	3.03	2.18	-1.47	0.14
Sawmill B	Total inhalable	10	1.189	16.905	1.84	57.09	9.54(17.82)	0.01	57.1	2.56		

* Mann-Whitney U Test

Table 2. Summary statistics of area respirable and total inhalable wood dust results at sawmill A & B

Sawmill	Wood dust type	No. of samples	GM mg/m^3	GSD	Median mg/m^3	Range	Mean (SD) mg/m^3	Min mg/m^3	Max mg/m^3	Skewness	Z- score	p-value*
Sawmill A	Respirable	2	0.132	0.09	0.16	0.18	0.16(0.13)	0.07	0.25	NaN	-1.50	0.13
Sawmill B	Respirable	4	0.799	0.50	0.75	1.59	0.96(0.69)	0.37	1.96	1.57		
Sawmill A	Total inhalable	5	0.132	0.164	0.1	0.35	0.2(0.18)	0.05	0.4	0.55	-1.92	0.055
Sawmill B	Total inhalable	6	0.537	0.554	0.49	1.6	0.68(0.61)	0.29	1.89	2.20		

* Mann-Whitney U Test

Table 3. Proportion of samples of personal respirable and total inhalable wood dust exposure levels below or above the action level and occupational exposure limit

Sawmill	Wood dust type	N	No. of samples < 2.5 mg/m³ Action Level	No. of samples ≥ 2.5 and < 5mg/m³	No of samples ≥5mg/m³ OEL
Sawmill A	Respirable	n=8	6		2
Sawmill B	Respirable	n=8	8		
	Total	**14**	**88% (n=14)**		**13% (n=2)**
Sawmill A	Total inhalable	n=8	7	1	
Sawmill B	Total inhalable	n=10	7		3
	Total	**18**	**78% (n=14)**	**6% (n=1)**	**17% (n=3)**

Table 4. Proportion of samples for area of respirable and total inhalable wood dust exposure levels below or above the action level and occupational exposure limit

Sawmill	Wood dust type	n	No. of samples <2.5mg/m³ Action Level	No. of samples ≥ 2.5 and < 5mg/m³	No. of samples ≥5mg/m³ OEL
Sawmill A	Respirable	n=2	2	0	0
Sawmill B	Respirable	n=4	4	0	0
	Total	**6**	**100% (n=6)**	**0**	**0**
Sawmill A	Total inhalable	n=5	5	0	0
Sawmill B	Total inhalable	n=6	6	0	0
	Total	**11**	**100% (n=11)**	**0**	**0**

the 5 mg/m³ OEL. However, 17% of the total inhalable dust samples were above both the action level and OEL (Tab. 3).

Table 4 indicates the proportion of samples for area respirable and total inhalable wood dust exposure levels below the action level. All samples for the area of respirable and total inhalable dust levels were below both the action level of 2.5 mg/m³ and 5 mg/m³ OEL at both sawmills A and B.

DISCUSSION

This study was conducted to determine the occupational exposure levels to wood dust among workers at timber processing sawmills in the Gert Sibande District Municipality. The results of 16 samples of personal respirable wood dust exposure obtained at sawmill A and B ranged from 0.09 – 13.57 mg/m³ and 0.14 to 2.25 mg/m³, respectively. The results of two personal respirable wood dust samples (9.12 and 13.53 mg/m³) at sawmill A exceeded both the action level of 2.5 mg/m³ and the OEL of 5 mg/m³. Moreover, the two personal respirable wood dust samples were higher than the 5 mg/m³ permissible exposure limit (PEL) set by OSHA and the 1 mg/m³ recommended exposure limit set by NIOSH and ACGIH TLV. These exposure levels, however, were lower than the exposure level of 31.75 mg/m³ reported in a study by Osuchukwu *et al.* at a sawmill in Calabar municipality, Nigeria [38]. Fourteen personal respirable wood dust samples at sawmill A and B were well below both the action level of 2.5 mg/m³ and the OEL of 5 mg/m³. The geometric mean of respirable dust at sawmill A was 0.88 mg/m³ and 0.57 mg/m³ at sawmill B. The study conducted at sawmills in New South Wales, Australia, reported a GM (GSD) of 0.33 (2.2) mg/m³ for respirable dust [7]. Another study conducted by Kalliny *et al.* reported geometric means of 1.44 (2.67), 0.35 (2.65) and 0.18(2.54) mg/m³ for inhalable, thoracic and respirable dust, respectively, at a sawmill in the USA [39]. Wood dust has some irritation and allergenic properties and exposure to higher concentrations may cause an increased risk for the upper and lower respiratory tract, inducing symptoms such as hypersensitivity pneumonitis or organic dust toxic syndrome, as well as airway irritations [1, 40].

The results of 18 personal total inhalable wood dust samples obtained at sawmill A and B ranged from 0.10 – 3.03 mg/m³ and 0.01 – 57.1 mg/m³, respectively. The time weighted average (TWA) for one personal total inhalable wood dust sample measured at sawmill A was 3.03 mg/m³ and exceeded the action level of 2.5 mg/m³, but was below the OEL of 5 mg/m³. Moreover, the TWAs of the three personal total inhalable wood dust samples at sawmill B were 11.10, 19.2 and 57.1 mg/m³, which exceeded both the action level of 2.5 mg/m³ and the 5 mg/m³ OEL. The TWAs for the remaining 14 personal total inhalable wood dust samples at sawmill A and B were well below both the action level and OEL. The mean exposure level for total inhalable dust at sawmill A was higher (0.72 mg/m³) than the mean exposure level of 0.2 mg/m³ reported in a study by Cormier *et al.* at a Canadian sawmill [41]. The mean exposure levels of 0.5 mg/m³ and 0.57 mg/m³ were reported in the studies by Chan-Yeung *et al.* and Ahman *et al.*, respectively, at sawmills [42, 43]. Previous studies by Halpin *et al.* reported the geometric mean of 0.7 mg/m³ for personal total dust concentration, which is similar to the mean TWAs for personal total inhalable wood dust concentrations measured at sawmill A in the present study [18, 19].

According to the results of the present study, the mean exposure level of total inhalable wood dust at sawmill B was 9.54 mg/m³, which is higher than the 1.4 mg/m³ reported by Hessel *et al.* and 1.42 mg/m³ by Schlünssen *et al.* [44, 45]. The studies by Holness *et al.* and Mandryk *et al.* reported mean values of 1.5 mg/m³ and 1.53 mg/m³, respectively, which were below the mean value for the total inhalable dust exposure level measured at sawmill B [46, 47]. Furthermore, Holmstrom and Wilhelmsson, as well as Goldsmith and Shy, reported mean exposure levels of 1.65 mg/m³ and 2 mg/m³, respectively [48, 49, 50]. Other studies by Andersen *et al.* and Pisaniello *et al.* reported mean exposure levels of 2.2 mg/m³ and 3 mg/m^3, respectively, while a mean exposure level of 3.75 mg/m^3 was reported in a study by Jacobsen *et al.* [51, 52, 53]. The higher exposure levels at sawmill B may be due to inefficient dust extraction systems, and the fact that workers were working close to the machines within an enclosed cabin with a limited supply of air circulating. The geometric mean for total inhalable wood dust exposure level at sawmill A was 0.37 mg/m^3 and below the geometric mean (GSD) of 1.44 (2.67) mg/m^3 recorded by Kalliny *et al.* in wood processing plants across the USA [39].

The lower exposure levels recorded at sawmill A may be due to the fact that the open shed area provided a good supply of natural ventilation which serves as a way of dispersing the dust by preventing it from building-up in the workroom air, even though the dust extraction systems may be ineffective, because dust build-up was seen on the floor. Futhermore, in both sawmills the fresh logs were sawn while wet, and this might have prevented the dust from being airborne, hence resulting in the lower exposure levels. The processing of fresh logs rather than dried timber in the sawmills may be a contributing factor for large diameter wood dust particles to settle more quickly to the ground, and which might not be measured. Moreover, fresh logs contain a higher percentage of moisture content and wood dust becomes less airborne, or if did become airborne it might settle more quickly on the ground than finer dried timber which takes more time to settle due to gravity. This could also account for the lower exposure levels in sawmill A. In another study by Hall *et al.*, the personal wood dust exposure measurements were collected by the Workers' Compensation Board of British Columbia and Canada in which the recorded geometric mean was 0.72 (3.49) mg/m^3 [54]. The GM(GSD) of 1.0 (2.7) mg/m^3 was reported in a study by Demers *et al.*, and 0.5 (3.1) mg/m^3 by Teschke *et al.* in a lumber mill environment [12, 13]. A study by Scarselli *et al.* to investigate the occupational exposure levels to wood dust at an Italian wood processing factory reported a GM(GSD) of 1.0 (1.6) mg/m^3, which was lower than that recorded at sawmill B in the current study [55].

The mean values of exposure level for area respirable wood dust at sawmills A and B were 0.16 and 0.96, respectively, and were below the mean exposure level of 0.33 mg/m^3 reported by Tobin *et al.* [56]. Furthermore, the mean values of exposure level for area total inhalable wood dust at sawmills A and B were 0.2 and 0.68, respectively, and were below the mean exposure level of 1.39 mg/m^3 reported in the same study by Tobin *et al.* [56]. Through this study, knowledge about the sawmill workers' exposure to wood dust in this setting has been disseminated. This will assist the sawmill industry in implementing measures to reduce the exposure of workers. High wood dust exposure levels were observed among workers operating the planer, destacker, saw dust remover, and saw dust extractor, due to the LEV design, hood fitted far away from the source. The dust lamp and smoke tubes can be used to check the effectiveness of the LEV system. Proper maintenance of the local exhaust ventilation (LEV) and regular testing of exposure are essential to mitigate exposure.

CONCLUSIONS

This study has highlighted the exposure levels for wood dust among workers in sawmills. Although the measurements for the majority of the samples were below the action level and OEL, there is a need to implement additional safety measures to protect the workers against the highest exposure levels recorded in other areas within the sawmills. To the best of the authors' knowledge, this is the first study to investigate the exposure levels of wood dust among workers in the sawmills in the Gert Sibande Municipality of Emolo, South Africa. Future studies should be conducted within sawmills in other provinces of South Africa. The following recommendations should be implemented at sawmills to reduce workers' exposure to wood dust:

- reduction of dust build-up in the workplace air, a high efficiency particulate air filter (HEPA) vacuum should be used instead of dry sweeping. Furthermore, on-tool extraction systems fitted with high HEPA filters should also be used to capture the wood dust at the source to prevent it reaching the employees breathing zone;
- a wet clean-up method such, as wiping surfaces with a wet rag or mop should be used instead of brushing, which can create airborne dust if there is no good ventilation;
- the number of workers performing dusty work exposing them to wood dust should be minimised, and the duration of performing such dusty work should also be reduced;
- a medical surveillance programme should be implemented in the workplace, in which the workers should undergo medical surveillance regularly for the early detection of underlying diseases and effective treatment;
- the use of respiratory protection equipment in demarcated respiratory zones is recommended in relation to the duration of exposure; the respiratory protection equipment should be inspected and maintained regularly to ensure its effectiveness in preventing wood dust exposure among workers;
- training and educating workers about the health risks of exposure to wood dust is important and should focus more on the necessity for control measures, safe work procedures, and how to protect themselves and identify when a ventilation system is not working properly;
- since smoking may increase the risk of respiratory health symptoms, workers who smoke should be encouraged to give up the smoking habit. cigarette.

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