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Review Article

Occupational Hygiene program for Wood Dust Exposure at the Timber Processing Factories

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Abstract

Exposure to wood dust can cause nasal and sinonasal cancer. Occupational hygiene program (OHP) for sawmill workers have not been studied extensively. It is known worldwide that sawmill workers are exposed to a variety of health hazards. Currently there is no comprehensive OHP exiting for the timber processing factories. The objective of this study was to develop an applicable OHP aimed at reducing worker's exposure to wood dust at the timber processing factories. Implementing an OHP is based on the HIRA for identifying potential hazards. The recommended controls are based on the exposure assessment conducted at the timber processing factories. In the timber processing factory, elimination of wood dust is an impractical measure to implement, hence, implementation of engineering and administrative control supplemented by appropriate use of fit-tested RPDs with higher APF is recommended to mitigate the exposure. Engineering controls include LEV hood fitted close to the source while administration controls include increasing distance from source far away from workers while PPE includes use of approved FFP2 respirators. This program will assist in reducing worker's exposure thus reducing occupational diseases amongst sawmill workers.

Keywords: Hygiene program, Air sampling, Risk assessment, Wood dust, Sawmill workers

Background

Occupational diseases have been documented long time ago, mainly on workers exposed to mercury sulphide [1]. The WHO estimated 386 000 deaths globally due to exposure to airborne particulates. This figure includes 152 000 deaths per annum due to exposure to carcinogens and 12 000 deaths per annum due to cancer and respiratory diseases [1]. The human body is a complex organism and is mostly affected by chemical agents such as wood dust [1-4]. Exposure to wood dust increases the risk of nasal and sinus cancers [5]. Likewise, exposure to *Iroko wood* and *Fraxinus Americanas* or *Thuja Plicanta*(a great western red cedar) increases the risk of occupational asthma [6]. The toxicity of wood dust is influenced by physical and chemical properties, concentration (dosage), duration of exposure, route of entry, diet, general state of the person's health, its absorption, distribution, metabolism and excretion in the human body [3,4]. A person with normal eyesight can recognize dust particles with diameter greater than 50μm while small dust particles bellow 10μm can only be seen with the use of microscope [7,8].

Timber processing factories or lumber mill generate fine dust particles that remain airborne for a longer duration and are considered hazardous to employees' health [8,9]. Since 1970, personal monitoring for wood dust in the employees' breathing zone has been conducted. This is despite high exposure levels being experienced in the past due to the lack of LEV systems and other methods to control dust [5,10,11]. Subsequently the 4IR and urbanisation has increased and introduced new hazards into the workplace [1]. The demand for sawn softwood and hardwood saw logs has prompted factories to buy faster sawing machines to increase production speed. This leads to fine dust particles being emitted during the process [11]. The introduction of engineering controls since 1950 has reduced exposure of workers considerably. However, engineering controls alone may not be 100% effective in lowering exposure [6,10,11].

Air monitoring programs for sawmill workers have not been studied extensively. It is known worldwide that sawmill workers are exposed to a variety of hazards. Currently, there is no comprehensive occupational hygiene program in place in timber processing factories. The objective of this study was to develop an occupational hygiene program aimed at reducing workers' exposure to wood dust in timber processing factories to help protect workers' health or well-being. An effective occupational hygiene programme includes anticipation and recognition of potential hazards at the workplace by conducting a health risk assessment

Health Risk Assessment for Wood Dust at the Timber Processing Factories

A detailed description of the steps to be followed when conducting a health risk assessment has been described in detail elsewhere [1-3]. Regulation 5 of the Hazardous Chemical Agents of 2021 requires a health risk assessment which is a program for determining any risk from exposure to hazards at the workplace to be compiled by a competent person with knowledge in industrial hygiene after consultation with safety reps or union in order to identify steps required to be taken to eliminate, minimize or control such hazards and this assessment needs to be revised once in every 24 months or suddenly when process changes etc. [12-15]. Controls are based on quantitative exposure data [5].

Thepaksorn et al. carrying out a health risk assessment of wood dust at the Para Rubber wood sawmills in Trang Province [16]. At the logging and cutting department the identified hazards were sawdust, fungi and molds. Likewise, exposure to fungicides was reported to increase the risk of respiratory symptoms, allergies and irritation. Chemicals, wood preservatives, and fungicides were identified as health hazards during vacuuming and wood treatment. Inhalation of chemicals was reported to increase the risk of respiratory symptoms, nausea and vomiting, eye and skin irritations [17,18]. Skin rash and skin irritations as well as eye irritations were observed on workers exposed to wood chips [16]. When sharpening blades, the identified hazards were fumes and mist. It was reported that exposure to fumes and mist might increase the risk of respiratory symptoms [16]. It was recommended for workers to use dust masks and chemical resistant gloves to protect against chemical exposure

Black, Dilworth and Summers carried out a similar risk assessment of wood processing factories at the British sawmills [19]. It was reported that the risk assessments conducted for production, maintenance, and cleaning were not exceptional. Joinery manufacturers, however, had written risk assessments in place that were implemented to reduce exposures to wood dust despite poor operations inside the mills. It was reported that having a COSHH written risk assessment was not a major contributing factor for controlling wood dust exposure. Sawmills that provided workers with information, instruction and training on the health risks of exposure to wood dust and control measures were 74% successful in implementing their controls. Despite the fact that other sawmills didn't have enough LEVs and the type of RPEs supplied were unlikely to be sufficient. Yet, 96% of workers were observed using brushes to clean despite 79% of the sawmills having vacuum cleaners while 64% were using compressed air to clean machinery and contaminated clothing.

Record of the Health Risk Assessment and Carry Out Actions

Risk assessments are critical as a preventative approach to health protection [2,14]. It is legal if it is documented in writing, dated and signed by the assessor. It is imperative to ensure that recommendations from any risk assessment are implemented properly. Many assessments fail to control exposure because actions are not implemented [2,14].

Review of the Health Risk Assessment

The health risk assessment should be reviewed periodically or frequently in an event whenever it is suspected that the assessment is no longer valid [3]. This is done in cases of process changes introducing new hazards, modification of existing controls, adverse symptoms liked with personal exposure monitoring, abnormal results of the health surveillance program e.g. lung function tests or biological monitoring, reported cases of occupational disease due to updated information on the risk(s) due to published epidemiological studies, review of new regulations in the absence of presence of known or unknown cases. The period between reassessments should depend upon the nature of the risk(s), the work and a judgement on the likelihood of changes. It is suggested that all risk assessments should be reviewed at least once every two years [1,3,14]. In the event that the results of the assessment indicate that employees may be exposed to significant levels via inhalation, air monitoring should be conducted [14,15]. An effective occupational hygiene programme for evaluation of occupational hazards includes air monitoring.

Air Monitoring for Wood Dust

When an airborne contaminant in the workplace air is at or above the action level or the OEL, detailed air monitoring must be conducted [3,14]. The details steps to be followed when conducting air monitoring have been described elsewhere in detail [1-2,14,20-22]. Regulation 6 of the HCA 2021 requires air monitoring to be performed by an AIA after consultation with safety reps or unions if wood dust can be inhaled by workers which must be representative of worker's exposure [13]. The regulation requires air monitoring which is a continuous process of observation, measurement and judgement of an airborne contaminant in the workplace air to be carried in accordance with Chapter 3 and 4 of Technical Appendix A of the OESSM with sample size to be selected for the top 10% of the group at 95% confidence level for agents with a control limit and top 10% of the group at 90% confidence level for agents with a recommended limit [13,20,21]. While chapter 4 discusses how to verify compliance with exposure, chapter 3 gives guidance on planning the sample strategy. According to Chapter 4 of OESSM, wood dust exposure should be classified as complying or non-complying in the monitoring records [21].

A comparison of the measurement results is made with the OELs described in Table 1 & Table 2 of adapted from the regulation for HCA 2021, thereby implementing control measures to reduce the exposure below the OEL to protect workers' health [13]. The OHS Act 85 of 1993 stipulates that air monitoring results must be presented to employees [13,14]. Plog, Niland and Quinlan indicated that there are five key elements to be considered when evaluating health hazards at the workplace which include the route of entry of the hazardous agent into the human body, concentrations and duration of exposure to the chemical to produce an illness, speed of generation of an airborne contaminant and the control measures that are in place etc. [8].

Table 1: Occupational exposure limits maximum limits for wood dust [13].

Agent	Cas number	Formula	RHCA-OEL PPM	RHCA-OEL MG/M³	RHCA-STEL/C PPM	RHCA-STEL/C MG/M³	Notations
Wood dust species, oak, beech, birch, mahogamy, teak and walnut	-	-	-	2(1)	-	-	CARC, RSEN

Abbreviations adapted partially from hazardous chemical agent regulation 2021 [13]:

CARC: means carcinogenicity based on GHS categorization, including category 1A and 1B; **mg/m³**: milligrams per cubic meter; **OEL-CL:** Occupational exposure limit control limit changed to **OEL-ML:** Occupational exposure limits maximum limits; ppm: parts per million; **RHCA**: Regulations for Hazardous Chemical Agents; **STEL**/Short-term exposure limit, ceiling limit

Notations [13]:

RSEN: respiratory sensitization or potential to produce respiratory sensitization; SKIN: danger of cutaneous absorption

Table 2: Occupational exposure limits - restricted limits for hazardous chemical agents [13].

Agent	CAS number	Formula	OEL Eight- hour TWA	OEL Eight- hour TWA	OEL-STEL/C	OEL-STEL/C	Notations
Wood dust species, oak, beech, birch, mahogamy, teak and walnut	-	-	-	5	-	-	CARC, RSEN

Abbreviations adapted partially from hazardous chemical agent regulation 2021 [13]: CARC: denotes carcinogenicity based on GHS categorization, including category 1A and 1B **mg/m³**: milligrams per cubic meter; **OEL eight-hour TWA**: Occupation exposure limit- eight-hour time-weighted average; **OEL- STEL**/C: Occupational Exposure Limit- Short-Term Exposure Limit, Ceiling limit; **OEL-RL**: Occupational exposure limit – recommended limit changed to **OEL-RL**: Occupational exposure restricted limits; **RHCA**: Regulations for Hazardous Chemical Agents

Notations [13]:

RSEN: Respiratory Sensitization, potential to produce respiratory sensitization; SKIN: Danger of cutaneous absorption

Air monitoring is crucial in investigating worker complaints. In addition, it can protect against compensation claims and assist in testing the effectiveness of LEV systems or selection of respiratory protection equipment [1-3,23]. Particle-size distribution studies have shown that the major portion of wood dust is contributed by particles larger than 10 μm in diameter, for which the use of inhalable samples is most suitable [11,24,26-28]. In Australia, Alwis tracked wood dust, fungi, and endotoxins in the workplace air [24]. They reported the geometric mean of inhalable wood dust exposure at logging sites of 0.56 mg/m³, sawmills 1.59 mg/m³, wood chipping mill 1.86 mg/m³ and joineries 3.68 mg/m³. Overall, 62% of hardwood exposure was greater than 1 mg/m³ NIOSH REL. At the joineries, 95% of the hardwood exposures and 35% of softwood exposures exceeded 1 mg/m³ NIOSH REL and 5 mg/m³ European Union (EU) OEL [25]. In addition, 70% of dry mill samples exceeded the hardwood OEL compared with 50% of green mill samples. Exposure levels of fungi at logging sites and sawmills ranged from 103 to 104 cfu/m³, wood chipping mills 103 to 105 cfu/m^3 and joineries 102 to 104 cfu/m^3. The predominant fungi found at the sawmills were *Penicillium spp, Aureobasidium, Aspergillus fumigatus, Penicillium spp. and Paecilomyces spp* [26]. The high inhalable wood dust exposure levels observed in the study were reported to be attributed to lack of awareness on possible health symptoms of exposure to wood dust on employees, aging equipment, inadequate or non-existence of LEV systems fitted on handheld tools, poor maintenance of LEV systems, dry sweeping, use of compressed air to clean machines and clothing and non-separation of dusty processes [26,28].

Rathipe and Raphela conducted a similar study at the sawmill factories located within the Gert Sibande District in Mpumalanga Province, South Africa [11]. It was reported that 78% of the personal total inhalable dust and 88% of the respirable dust samples were below 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 the OEL. In contrast, one sample of personal total inhalable dust was above the action level but below the OEL. However, 17% of the total inhalable dust samples were above both the action level and the OEL. The higher exposure levels at sawmill B were reported to be due to inefficient LEV systems and the fact that workers were working close to the machines that generate excessive dust. The high levels of respiratory dust exposure at sawmill A at the planer (9.12) and detacher (13.57) and a saw dust remover (57.1), saw dust extractor (11.10), and saw dust extractor (19.2 mg/m^3) at sawmill B, were reported to be due to LEV design, hoods fitted far from the source. It was recommended the sawmill manager to provide proper maintenance of the LEV and regular testing to reduce the exposure levels [11].

Tobin, Ediagbonya, Okojie and Asogun also conducted similar study at the South-South Nigeria [29]. They reported the mean (SD) exposure for total dust of 1.39(0.28) for exposed than 0.52(0.07) mg/m^3 unexposed and the dust exposure levels ranged from 0.94 to 1.67 for exposed and 0.83 to 1.67 unexposed and the mean (SD) exposure for inhalable dust was 1.07(0.34) for exposed and 0.44(0.09) unexposed with the dust exposure levels ranging from 0.60 to 1.66 for exposed and 0.31 to 0.53 unexposed with levels of dust exposure ranging from 0.17 to 0.57 exposed and 0.10 to 0.31 unexposed. The mean(SD) exposure for respirable dust was 0.33(0.12) for exposed and 0.23(0.08) unexposed. The higher levels of wood dust at the sawmills were associated with a higher prevalence of upper airway irritation among sawmill workers. However, in contrast, lower exposure was clarified by the fact that operations such as debarking, sawing and cutting produced dust with a diameter greater than 10 microns when processing fresh logs, and that dust settles quickly to the ground in both surveys, the high levels were attributed to the absence of LEV systems. The low recorded results were attributed to the study site being open sheds with good ventilation serving as a means of dispersing dust and preventing it from being airborne. Area sampling gave lower values, which led to an underestimation of worker exposure. The value of respirable dust was lower because of the difference in the air sampling equipment used.

Teschke et al. conducted unrelated study in US timber processing factories [30]. They reported that the exposure levels ranged from 0.03 to 604 mg/m^3, with an arithmetic mean (GM) of 7.93(1.86). The results decreased substantially when compared with the geometric mean of 4.59 mg/m^3 in 1979 and geometric mean of 0.14 mg/m^3 in 1997. The highly exposed jobs were sanders with geometric mean of 17.5 mg/m^3, press operators 12.3 mg/m^3, lathe operators 7.46 mg/m^3 and sanders 5.83 mg/m^3. Scheeper, Kromhout and Boleij also carried out an 8-hour personal and ambient sampling for inhalable wood dust exposure at the joineries and a furniture manufacturing factory in Netherlands [31]. It was reported that almost all personal exposure levels obtained at the wood processing factories and joineries were greater than the health-based limit of 0.2 mg/m^3 and were considered to pose a significant risk to worker's health. However, Thepaksorn also conducted a not the same study in Thailand and reported the maximum wood dust exposure of 2.500 mg/m^3 for respirable dust and 2.083 mg/m^3 for total dust [16]. The levels were above 1 mg/m^3 NIOSH PEL, especially in the processing of lumber into sheets and planning and re-arranging. The authors recommended the use of dust masks and maintenance of the extraction hood duct to provide better ventilation.

Osman and Pala conducted parallel study at the furniture industries in a minor industrial estate in Bursa/Turkey [32]. They reported an average wood dust exposure of 2.04 ± 1.53 mg/m3 and 0.0006 ± 0.00025 mg/m3, respectively. Even though exposure levels were relatively low, there were no ventilation system in place at furniture manufacturing factories because 9.5% of workers were exposed to wood dust above 5 mg/m3 TLV recommended by Turkey while 16% of workers were exposed to respirable dust above 5 mg/m3 and 79% were exposed to respirable wood dust above 0.5 mg/m3, maximum admissible respirable wood dust level recommended by SCOEL. It was recommended that controls be put in place at the sawmills, and workers to be educated on the important of using PPE while at work [1,3,11,24,29]. Similarly, an effective occupational hygiene programme for evaluating occupational hazards at the workplace must include methods, sampling strategy, equipment to be used, calibration, sampling media, laboratory and statistical analysis of samples to compare the results with OEL.

Methodology

A systematic literature review using Google Scholar; Science Direct; PubMed; Scopus etc. was conducted to identify studies conducted on risk assessment and air sampling for wood dust at the timber processing factories. This was done in order to develop occupational hygiene programmes aimed at reducing workers' exposure to dust at the timber processing factories. Methods for sampling dust for assessing workers' exposure at concentrations at or above OEL are specified in detains on NIOSH, OHSA and HSE guidelines for sampling inhalable, thoracic and respirable dust [20,33-38]. Personal monitoring is conducted to get reliable estimates of worker exposures to airborne particulates. The validated sampling method used must be adapted from previous studies [5,6,16,19,24,25-27,30-32,39-43,47-49]. Overall occupational hygiene program for sawmill workers at the timber processing factories is outlined in Figure 1.

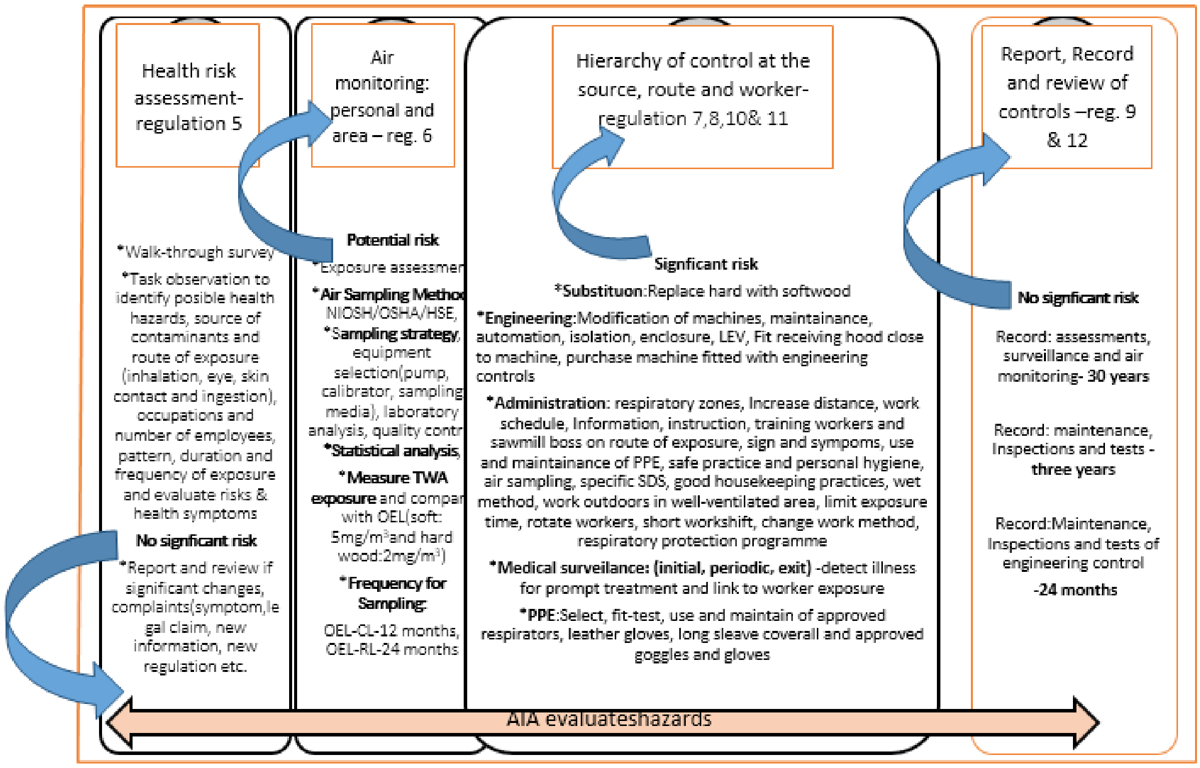

Figure 1: Occupational hygiene measurement program for sawmill workers at timber processing factories.

Sampling Strategy

There are two types of sample strategies used to monitor personal exposure to wood dust, which include representative and worst-case sampling [2,14,20]. Samples taken from representative samples can take into account influences from timber processing factories, while worst-case samples can be taken where high-risk workers can be identified [2,14,20]. Employees presumed to be highly exposed to dust at or above OEL can be selected for sampling. In every operation, however, the maximum risk employee must be selected depending on the process. If the maximum risk employee cannot be identified in an operation, a group of employees who perform similar tasks are grouped together for a random sampling of groups with high risk of exposure [2,14, 20, 21]. This sampling strategy has been described in detail elsewhere [2,12,14,20-22]. In order to select the most accurate sample, you should select employees who have been highly exposed [2,14,21]. Leidel, Busch and Lynch indicated that five samples would be enough to be sure 90 percent of the time that one sample will be taken 33% of the time on the worker with the highest exposure [21]. In situations where there are fewer than ten employees in a SEG, only five employees need to be included in the monitoring exercise. However, in cases involving more than ten employees in the group, the OESSM or BS EN 689 sample strategy should be employed [2,14,20]. Once the number of workers to be sampled is known, a random number Table 5 can be used to randomly sample those employees and measure their exposure [2,14,20,21].

When planning for an assessment, consideration must be given to the homogenous exposure group (HEG), maximum risk employee (MRE) and group sampling (GS). Maximum risk employee(s) is evaluated to determine if employees may be exposed to wood dust at concentrations above action level or OEL [14,20,21]. As a result, the air sampling pump must be placed on the worker with the highest risk of exposure to ensure it represents all workers. There are factors that need to be considered when selecting MRE, this include workers closest to the source of emission, if a worker that is closest to the source has high mobility he might not be the MRE and will require careful observation to identify MRE, worker position towards the job when performing the task as per the SOP and air movement patterns can influence selection of MRE as well as worker distance from the source [14,20,21]. If maximum risk employees cannot be selected in an operation, then a random sample of a group of workers with similar expected exposure risk (HEG) or (SEG) is selected [14,20,21].

It may be necessary to observe the workplace or task to determine if there are groups of workers who are exposed similarly to one another. If so, such workers must be grouped together in HEG and representative samples must be collected from each group [14,20,21]. If MRE cannot be achieved, group sampling (GS) will be an alternative. GS is based on random sampling (RS) of the number of workers from each HEG following the OESSM procedure [21]. The purpose of group sampling is to include 10% of workers with the highest exposure. To ensure that GS is representative of the group exposed, a sufficient number of workers must be enrolled to ensure adequate confidence. It is required to have a confidence limit of 95% for substances with control limits. However, a confidence limit of 90% should suffice for substances with recommended limits [14,20,21].

Group sample selection (GSS) requires dividing the workers into HEG and selecting from Table 3 or Table 4 for number of employees to sample per group considering whether agent is a control limit or recommended limit and number the workers as per the HEG and use Table 5 random number table to select the workers who will be included in the sample group [14]. The results need to be carefully analysed to ensure that they are equally valid for all employees in the HEG. A wide difference in the results from different individuals indicates considerable variation within the HEG [14,20,21]. Air monitoring for wood dust must be undertaken every 12 months for substances with OEL-CL and every 24 months for substances with OEL-RL [13]. Judging is part of the interpretation of results. Air monitoring is an efficient tool to protect workers' health and assist in the control programmes. Where the assessment indicates a risk to health, it is necessary to specify the steps to be taken to achieve effective control including subjecting employees to medical surveillance programs.

Table 3: Sample size for top 10% and confidence 0.95 (Use n = N if N ≤ 11) [14].

Size of Group (N)	12	13-14	15-16	17-18	19-21	22-24	25-27	28-31	32-35	36-41	42-50	∞
Required number of measured employees (n)	11	12	13	14	15	16	17	18	19	20	21	29

Table 4: Sample size for top 10% and confidence 0.90 (Use n = N if N ≤7) [14].

Size of Group (N)	8	9	10	11-12	13-14	15-17	18-20	21-24	25-29	30-37	38-39	50	∞
Required number of measured employees (n)	7	8	9	10	11	12	13	14	15	16	17	18	22

Table 5: Random number table to select the workers to be included in the sample group [14].

10	15	1	2	81	91	69	14	62	36	20	99	91	90	22
46	25	85	30	89	27	53	93	34	52	19	39	99	24	48
22	97	76	64	15	24	49	32	30	19	63	58	42	93	6
61	7	16	39	53	71	57	0	74	97	16	37	39	81	16
6	91	60	81	49	60	14	6	1	54	77	6	11	42	27

53	18	70	90	15	21	81	44	42	99	72	56	69	98	31
71	18	44	48	63	21	10	12	96	91	5	7	18	20	94
56	69	60	18	84	42	32	89	14	65	10	17	18	57	84
25	12	58	44	5	56	85	36	53	53	53	59	38	62	8
17	16	11	18	64	28	69	88	33	70	79	56	5	90	31
1	85	91	78	63	40	48	3	49	69	18	72	52	20	12
90	33	90	9	93	52	92	88	33	36	17	30	8	84	27
30	74	10	61	87	85	48	52	67	93	1	26	85	20	29
89	7	97	71	8	77	13	47	81	97	85	29	74	28	90
51	12	51	51	77	16	60	92	49	53	70	63	75	40	2
21	52	60	89	19	55	44	1	65	64	44	5	55	1	54
33	94	31	4	18	29	71	85	51	1	92	64	52	53	46
58	23	14	83	98	23	64	94	17	35	35	7	97	33	9
42	6	76	13	51	46	88	19	25	58	48	91	85	14	9
30	90	4	59	22	30	61	99	32	54	58	22	74	47	25
76	26	58	6	21	15	96	11	32	32	5	24	13	38	94
28	35	6	17	64	18	22	29	27	87	87	58	0	45	15
46	41	10	7	36	18	2	33	28	7	19	92	60	61	50
67	32	86	50	94	13	16	74	92	24	36	0	22	2	51
7	79	97	45	21	0	30	3	94	89	41	17	27	63	41
49	82	24	99	47	81	64	66	80	65	83	34	13	30	97
35	91	0	50	98	38	87	94	39	57	67	77	44	11	71
11	60	6	28	37	7	98	98	27	31	80	44	97	70	95
14	50	35	59	87	48	2	0	48	4	21	20	92	90	12
35	1	0	38	28	68	10	10	54	6	50	65	79	53	10
72	77	56	55	87	69	45	0	25	0	96	30	47	23	39
56	20	21	51	33	72	32	41	76	91	21	36	27	73	20
37	63	71	84	52	22	78	17	96	18	70	66	99	72	1
42	11	20	54	36	70	23	65	59	99	94	11	18	81	80
90	52	2	85	88	47	0	82	72	15	43	99	10	76	25
3	21	83	43	90	22	44	34	65	59	43	38	59	13	35
1	39	76	22	83	82	79	29	4	72	55	12	66	38	22
73	88	9	82	5	57	82	27	32	65	15	98	63	11	34
88	56	34	57	23	7	40	67	12	4	14	23	35	99	37
11	35	85	9	96	33	97	28	14	32	80	70	75	76	88
37	40	59	33	26	88	69	76	50	43	86	70	79	93	28
19	68	69	88	49	43	63	56	0	73	91	15	6	57	54
17	0	64	60	88	61	96	30	43	11	44	34	60	60	71
60	63	71	5	43	58	26	32	73	35	57	10	54	54	93
85	64	29	44	14	55	78	73	11	48	51	9	10	24	11
65	52	50	22	5	99	73	14	35	70	60	18	9	42	8
43	47	42	45	0	20	14	49	94	56	59	9	58	29	44
45	70	5	49	26	57	99	24	74	75	28	39	52	62	72
98	67	72	1	13	14	87	89	13	77	69	70	70	34	15
81	58	35	94	75	0	97	96	86	96	86	54	54	55	41

Sample Collection Technique

There are three types of sample collection techniques used to monitor wood dust, involving personal, breathing zone, and general air or area sampling. Personal sampling is obtained when a worker wears an air sampling pump for an interval during their shift. It is used to establish the concentration of an airborne substance within the employee's breathing zone (within 30cm or 300mm radius of the worker's nose and mouth) [22]. The sampling device, inlet and tubing must be positioned in such a manner as not to interfere with worker movement or task [3,14]. Samples collected in the breathing zone of a worker are termed personal samples and are directly linked to workplace OEL [50]. Breathing zone samples are when the sampling device is held by the second individual who attempts to sample air in the worker's breathing zone [10,20,21]. While general air or area sampling is when the sampler is placed in a fixed location in the work area. This is to provide information about contamination from fixed sources or the effectiveness of control measures [2,3,20,37,51]. Area samples do not normally reflect actual personal exposures to wood dust [2,3,11,36]. The sampling heads should be located at approximately head height and as near as possible to the job locations or as near as is possible to sources of emission of airborne dust and away from obstruction of fresh air inlet or strong wind [14,20,22,36,37]. However, fixed position samples cannot be used to establish personal exposures or be compared to hygiene standards [1,2,14,20].

Sample Equipment

Personal air sampling equipment, apparatus, preparation of filter holders before use, calibration of pump and personal sampling procedure have been described in detail elsewhere [1-3,14,22,24,34-37]. No single piece of equipment is available that is suitable for all types of sampling. When performing personal sampling for airborne particulates there are three main sampling system components required such as the pump, filter and sampling head [2,51]. The pump should be able to operate at a constant flow rate of between 1 and 2.5 litres per minute for long periods of up to 8 hours [3,14,34-37,51]. The filters need to be capable of collecting all the particulate material that is brought into them. They also need to be compatible with any subsequent analysis technique [3,14,51]. Typically, these are glass fibre filters and membrane filters [33]. When dust analysis is required, a glass fibre filter is used. The filters are weighed before and after use so that a weight change can be determined [34,35,37]. This change in weight can be used with the flow rate and measurement time to arrive at a determined exposure using the equation [1,2,14,34,35,37]. The sampling head allows the filter to be held in the correct position but can also act as a size separator. Total inhalable dust is typically measured using the IOM sampling head although other devices are also available [3,36,37]. Respirable dust is measured using a cyclone pre-selector which removes larger particles before they reach the filter [2,3,33,35-37,51].

Sample Duration

Duration of monitoring depends on the sensitivity of the sampling and analytical method, duration and frequency of exposure. The OEL is prescribed for an agent sampled for 8 hours TWA, while the STEL is prescribed for substance sampled for 15 minutes [50]. To be representative of worker exposure, samples need to be taken 70 to 80% of the time [21]. To reduce sample time, the unsample portion must be accounted for and this requires observation of workers performing the task [3,21].

Types of Sampling Taken for 8 hours or 30 minutes'

There are three types of monitoring periods be made up of8-hour shifts, short-term exposures (STEL), and ceiling limits. The term "full period sample" refers to a sample gathered over 8 hours. Several samples can be obtained for 8 hours TWA or 15 minutes with ceiling parameters [2,21]. STELs is15-minute exposures which should not be exceeded at any time during a workday even if the 8-hour TWA is within an acceptable level while the ceiling level is the maximum exposure that should not be exceeded during any part of the workday [50]. A partial period sample is a single sample obtained for 4 hours, and multiple consecutive samples can be obtained for 8 hours or 30 minutes. Samples that are randomly selected last for a short period of time, for example, 5 to 8 hours during the course of the day; these may be collected over a short time span, such as minutes or seconds [3,21]. Taking consecutive samples that last for the full period is the best strategy as it allows for the most precise confidence intervals in the results. A full-period single sample is the next most suitable option, followed by a partial-period consecutive sample. The least preferred method will be to collect grab samples [3,21].

Regardless of the strategy chosen, it will be detrimental to consider several factors that will influence the sample strategy, including the availability of sampling equipment, analytical facilities, workers and work locations, and the precision and accuracy of sampling and analytical methods. Number of samples required to obtain the required accuracy. Where it will be worse case sampling or group sampling to be performed [20]. Inter day and intraday variation in concentration while research has shown that interlay and intraday variation in exposure lie between 1.25 to 2.5 [3,21]. It is estimated that the precision and accuracy of NIOSH sampling and analyses vary from 0.05 to 0.10 [3,21].

Ethical Concerns

Ethical consideration must be obtained from the ethical committee of a relevant university with a reference number. All the participants must be clearly explained the purpose of the study and agreed with their signed in inform consent. Permission to perform the study must be obtained from the managers of the factories and participating workers.

Statistical Analysis

Data must be analysed using a statistical package to obtain a summary of descriptive statistics. Both the geometric means and standard deviation, as well as the minimum and maximum values, need to be calculated and if data is not normally distributed, other test to be used to test the significance of the differences between the values. A significance level of 0.05 may be applied.

Recording of Results and Sampling Records

Adequate information must be recorded to ensure the results can be evaluated properly and correctly. Under the regulations for hazardous chemical Agents of 2021, air monitoring records must be kept for a period of three years [13]. A field calibration procedure must be established for equipment to ensure quality [3,14]. The laboratory involved in analysis must have an occupational hygiene quality system in place like SANS 0259. Use of equipment must be referred to in the manufacturer's instructions for obtaining accurate results [3,14,53,54]. Full details of the sampling performed must be documented and retained [3]. The record should indicate when the monitoring was done, who and where it was monitored, details of the equipment used, the operations in progress at the time of the survey and the results obtained. Most regulations require records of sampling to be made accessible to workers or their reps [1,3,13,14].

Classification of Occupational Exposure

The purpose of classifying occupational exposure is for statistical categorisation of exposure as complying or non-complying, determining compliance with OEL, determine part of the days an employee can be exposed to concentrations above OEL and to determine if engineering control must be instituted [3,14,20,21]. OEL is defined as the maximum concentration of an airborne hazardous chemical agent to which an employee can be exposed every day for the duration of his or her employment without experiencing any adverse health effects [3]. They are expressed as mg/m^3 or ppm and serve as a guideline for safer exposure levels. It is a good practice to keep the level of exposure at or below the action level, which is half or 50% of OEL [3,21,51]. In accordance with regulations, the level must be low as possible. Amongst the problems linked with the use of OEL is that agents are not only inhaled but can also be absorbed through the skin. To sample the total absorbed dose, biological monitoring must be carried out simultaneously with air sampling. OEL were set for an 8-hour exposure per day (40 hours per week) and were set for individual exposure, yet the health effects of exposure increase when exposed to quite a number of agents with similar health effect. Health status, smoking and individual susceptibility also play a role. The results of ongoing research have led to the lowering of the wood dust standards to 1 mg/m^3. However, the standard fails to protect against cancer due to workers not wearing respirators [1,2,14,21,51].

The control limit and recommended limits give an 8h TWA exposure limit because they cause chronic effects. In fact, agents are assigned TWA and STEL as they may cause chronic health effects after prolonged exposure to low concentrations [3,14,21]. If exposure cannot be reduced, protective equipment must be issued to workers and trained on proper use [3,13]. An effective occupational hygiene programme involves revising controls measures in place in order to propose appropriate control to reduce occupational hazards to protect worker health

Reviewing of Control Measures Used at The Timber Processing Factories

Relevant control for wood dust exposure comprise of engineering, administration and personal protective equipment for reducing exposure to an acceptable level. The levels to which it be tolerable to workers without impairment to their health and productivity [8,54,55]. Preventive measures must be directed to the source of contamination. This involves isolation or enclosure of the source or the employee [3]. Separating the source from the worker while using ventilation to trap the contaminant at the source will prevent dust from dispersing and reaching the worker. Control along the path, when the contaminant is dispersing, is more difficult to control but then again general ventilation which dilutes the contaminant concentration can be employed as well as increasing the distance between the source and the workers so that there is more dispersion and dilution of fresh air [3]. Worker based controls can be facilitated by rotating, limitation of worker exposure and the length of time they work in dusty areas while wearing respirators to stop inhalation of the contaminant [3]. In the hierarchy of control, the use of engineering controls should be considered first [8]

Engineering Controls: are used to engineer hazards either during the initial design stage or by applying methods similar to isolation, enclosure or ventilation. In order to reduce dust exposure, focus should be on local exhaust ventilation and cleaning methods. It is crucial to ensure effective LEV at all woodworking machines and to professionalize cleaning to avoid use of compressed air by increased use of vacuum cleaning with high HEPA filters [3,56]. Alwis *et al*. conducted a study at New South Wales Australia [25]. It was reported that none of the green mills were equipped with LEV systems. However, Mandryk, Alwis and Hocking reported that use of old equipment, poor maintenance of LEV systems and escape of wood dust from the joints of the LEV system into the workroom air were the contributing factors to the high wood dust exposures at the sawmills [9]. Alwis, Mandryk and Hocking *et al.* reported that the highest wood dust exposure levels found among joineries workers were due to inadequate and inefficient LEV systems, use of handheld tools and compressed air to remove wood dust from the surfaces, timber floor and workers clothing [25,26,28]. Sawmill is an open shed which provides good supply of natural ventilation which serve to readily disperse dust [26,28,29]. AIHA considers dilution ventilation to be less effective if the outside air is more contaminated that the inside air and workers are less than 1meter in the vicinity of emission sources [3]. For this reason, displacement ventilation will work effectively if the ceiling height is higher than 3meter [3].Debarking or planning process produces large diameter dust that settle to the ground [29]. Therefore, use of HEPA vacuum cleaning is required than dry sweeping [3] Black, Dilworth and Summers reported that the efficiency of LEV system can be demonstrated by use of dust lamp and smoke tubes to be effective [19]. Dust lamps and smoke tubes are used to track dust dispersion by illuminating extra-fine dust not visible to the naked eye [3]. Typical faults in the LEV system was reported to include poor balance of the LEV between machines, hole in filter bags, split joint in ducting, poor connections, captor hood fitted far from source, air movement pattern, worker position, dust from saw blown towards operator, smoke blown away when machine switched on [19]. Companies that carried out 14 month testing and weekly checks on LEV systems were reported to be more effective in controlling wood dust than those that did not, but even under these conditions an LEV system may not be 100% effective in reducing exposure and must be supplemented by other controls [11,19].LEV alone cannot provide adequate control of wood dust exposure. EN 12779 recommended a residual dust content in the return air to be 0.3 mg/cm3 [46,58-63]. This standard requires constant monitoring of returned-air with an air flow capacity greater than 10 000 m^3/h [42].

In general, LEV is more effective than general ventilation as it removes airborne particles at the source [3, 64]. General ventilation should not be used where there is a major, localized source of contamination, especially highly toxic dusts [3]. There may be potential sources of dust dispersion in certain processes, which should be controlled either by wet methods or by enclosures. Points where conveyors are loaded or discharged should be enclosed. Where it is not possible to enclose or isolate the process, ventilation or other control measures should be provided [3]. Sanding with a hand-held sander can be reduced by a dust collection box attached to the hand-held sander [65]. However, even with significant reductions, an on-tool system for sanding dust collection will not entirely eliminate exposure and must be supplemented by the use of respiratory protection. Sanding workers had the highest dust exposure. In comparison, sanding operations produce 22% of the respirable fraction compared to 6 to 14% in other woodworking processes [66]. NIOSH proposed a new system to be used on rotating hand Sanders. The newly designed system captures wood dust directly from the finished surface at the pad periphery. In the laboratory, the newly developed control system reduces wood dust emissions by 90% [67]. In order to detect leaks in the air-cleaning system when cleaned air is returned to the working areas, dust content in extraction systems must be monitored [68] with an after-filter and the amount of pressure drop across the filter [3]. Sanding with both stationery and handheld powered tools, and cleaning with brushes and compressed air are the main sources of exposure in woodworking shops [69]. The use of ventilation to control exposure has its own problems [70]. However, the problems are likely to be more severe in smaller companies due to finance issues. Maintenance of LEV systems have emerged as an essential for achieving efficient control in several woodworking industries [19]. Respirable dust can be controlled by general ventilation at a rate of 0.7 to 4.2 m^3/min, according to Ojima[71].

Mikkelsen et al*.* proposed automation of woodworking machines and processes to reduce wood dust exposure when manual sanding is used and ensure efficient LEV at all woodworking machines. Balance general or LEV by the intake of supplementary fresh air, clean production areas daily by specialists and prohibit use of compressed air to clean machines [42]. Using a vacuum system as brushing work piece induces the introduction of dust into the worker breathing area, but effective ventilation can remove the airborne dust it creates. It is not recommended as general practice, butHSE recommends the use of vacuum cleaning [64,72]. Inclusion of a performance indicator in LEV ductwork is an effective practice that assists weekly checking [42].

There are some sawmills that employ a central dust collection system in order to capture dust at the source. Therefore, pitot tubes or slack tube manometers can be used to evaluate the performance of the system at least 7.5 duct diameters downstream from major air flow disturbances, such as elbows or hoods, in accordance with the ACGIH ventilation manual [3,57]. Velocity pressure of the LEV system can be measured in the main duct and optimum airflow calculated by adding the recommended airflows according to the ventilation manual [19,58-64]. A minimum of 6 points are required for a round duct less than 15cm in diameter, while a minimum of 10 points is required for ducts more than 15cm in diameter while large ducts or wide variations in velocity are better suited to a minimum of 20 points [3]. Pitot tubes are usually not considered reliable to measure airflows with velocities less than 3 m/s [3]. LEV must be examined and tested at least once every 14 months and records kept for at least 5 years [13]. The duct velocity of the LEV must be maintained at 3500 feet per minute to effectively remove dust and prevent it from plugging the system. LEV systems with a duct velocity of 20 m/s and face velocity of 1.0 to 2.5 m/s should be selected before installing an LEV system [3]. It is recommended to use the electrostatic precipitator for particles with a diameter between 5 to 10μm without electrical conductivity as it has a performance of 99% or the cyclone for particles with a diameter of 8μm as it has a performance of 90% [3]. Low Volume High Velocity

(LVHV) capture hoods can be used on belt sanders and hand tools with a velocity between 50 to 100 m/s [3].

Administrative Controls: if the engineering control are not practicable in implementation it will be suitable to organize work schedules and lessen exposure time so that employees are minimally exposed for few hours to the health hazards. Employees who have reached their upper permissible limits of exposure can be transferred to an environment where no further additional exposure will be experienced [3]. Where exposure levels exceed the PEL for one worker in one day, the job can be assigned to two, three or as many workers as needed [3]. This is to keep each individual's exposure duration below the PEL [1,3]. Yamanaka et al. reported that levels of wood dust exposure in their study were higher for the clean-up workers (3.5 mg/m3), followed by maintenance, planer, and sawmill occupational groups [47]. The Alberta Forest Products Association undertook a program to train sawmill managers on the hierarchy of controls such as engineering controls, administrative controls, and personal protective equipment [47].

It is vital to educate and train workers on the routes of exposure to health hazards, signs and symptoms of the respiratory illness like cough, phlegm, breathlessness, wheezing and nasal symptoms [6]. Worker to practice good hygiene practices like frequent showering and hand washing, especially before meals, and do not eat, drink, or smoke within designated respiratory zones [1,3]. Training workers on possible sources of exposure and control measures will limit exposure to the health hazards [3]. In-house training can be provided on the use and benefits of PPE [19]. Information, training and coaching would enable workers to make proper use of PPE [67]. Kitcher*et al.* reported that 100% of LG workers had formal training for their jobs, then34% of the sawmill workers [73]. Black, Dilworth and Summers indicated that three furniture manufacturing factories provided health surveillance and nasal cancer screening whereas two other sites provided lung function tests and respiratory symptoms questionnaire and skin inspection and another two companies provided pre-employment screening without health surveillance [19]. Health surveillance is crucial in linking reported disease to worker exposure for early treatment and relocating the exposed worker to leases exposed jobs. If administrative control is not practical to implement it may be wiser to resort to PPE

Personal Protective Equipment (PPE): PPE is used as a last resort in the hierarchy of control due to its disadvantages which are noted elsewhere [1,2,3].Osagbemimi *et al.* reported low use of PPE among sawmill workers due to various reasons [74]. Bamidele also reported non-use of PPE due to non-availability [75]. Employers are responsible for providing PPE free of charge to employees suitable for the risk involved and offer training to ensure effective use of PPE [76]. This is critical, as employees may not be aware of the health effects of wood dust exposure at work [67]. Generally, apart from PPE's not being properly used, there was a lack of enforcement in their use [77-79,81]. Only about one in four workers may be trained on the use of PPE, and half of the workers rarely or never wear PPE while working [16,18,46,82-84]. Ninety-five percent of workers may be aware of the potential hazards of exposure to sawdust but less than 20% of workers wore dust masks [85]. Thirteen percent (13%) of workers may use PPE consistently while 38% of workers forgot to use PPE [86].

Advertisements of tobacco have adversely affected anti-smoking laws in many countries [87,88]. Since more than half of workers rarely use PPE such as mask, they are still at high risk of exposure to dust. The use of appropriate PPE while at work would help to protect from developing more severe chronic respiratory diseases in the future [46]. The FEF25-75 was reported to be higher on workers who wore dust masks [32]. Alwis reported that 90% of workers do not wear suitable respirators approved for wood dust while those who wear them use them on average less than 50% of the time [24]. Workers should be protected by controlling dust at its source. When dust exposure cannot be controlled at the source, use of appropriate PPE must be made mandatory [3,24-28]. Selection, fit test and wearing of respirators must be included in the program [3,78,89-92].

Choice, comfort, maintenance and PPE management programmes are crucial in PPE selection [3]. Fit testing and training are discussed in detail elsewhere [1,3,78]. PPE has been reported to have one serious drawback, they do not reduce or eliminate the hazard and impose a barrier between worker and hazard, if the barrier fails, immediate exposure result [3,77]. The supervisor must make sure that required PPE is worn by workers who need supplementary protection, as may be required by OSHA standards [8,77]. Elements of a written respiratory protection program must be in place at the sawmills [91].

Maintaining proper housekeeping: Proper housekeeping plays a key role in occupational health protection. Basically, it is a key tool for preventing the dispersion of dangerous contaminants and for maintaining safe and healthy working conditions [3]. It is impossible to have an effective occupational health program without proper maintenance and housekeeping. Vacuum cleaners can minimize dust leaks, but other methods, such as wet cleaning, should also be used to reduce dust hazards [8]. Systems such as venture scrubbers, cyclones, etc. can reduce dust emissions by up to 95% [3].

Discussion

The protection of workers against ill-health from exposure to wood dust is part of the ILO mandate [93]. The aim is to promote decent work that will create more jobs to improve economic growth of the country [93]. According to ISO, all organisations have a moral and legal duty to protect workers' health against exposure to environmental stresses at the workplace to reduce occupational diseases [94]. The OHS management system model such as ISO 45001 is based on Plan-Do-Check-Act cycle[94-96]. The intended outcome of the OHS management system is to provide a safe and healthy workplace(s) by preventing occupational diseases[94]. An OHS management program for reducing occupational diseases must be prepared and reviewed by senior management to ensure it remains relevant to the contexts of the organisation[94,97-99]. The program must be available to interested parties including workers and clients to by-in and for implementation

According to United Kingdom (UK) and European Union (EU) laws, there are a number of legal requirements for wood dust that apply to factories and extend beyond the workplace to those who may be affected [94]. With the advancement of technology, complexity of sawmills and the interaction of workers with new forms of hazards, management of health and hygiene need to develop a new approach to be able to minimise risks to protect worker's health[97]. It is vital for an organization to establish, implement and maintain its OHS management system when identifying hazards, assessing the risks and determining appropriate controls to be implemented [94,98].

Conclusion

The objective of this study was to develop an occupational hygiene programme aimed at reducing worker's exposure to wood dust at the timber processing factories. An OHS management system will help promote continuous improvement of occupational hygiene at the processing factories. Top management commitment and worker's participation is vital in the implementation of an occupational hygiene management system in an organisation. Emphasis will be on workers taking an active role in OHS matters, this can have positive benefits to the processing factories in terms of their staff retention, motivation and productivity. The programme encourages management and workers' participation when identifying hazards, reducing risk by implementation of a hierarchy of controls integrated with other business processes. This approach will improve safety culture, minimise risk and embed best practice resulting in reduction of work-related diseases.

The factories have cause a need for an up-to-date industrial hygiene program that contains the latest information to address job related illness that may be contracted by workers while at work. An effective occupational hygiene program (OHP) include anticipation and recognition of occupational hazards and evaluating the magnitude of the hazards while putting control in place to reduce the hazards to help prevent workers' health [8]. The industrial hygienists are crucial in the supply of information on the work practices and the associated hazards to enables the medical practitioner or doctor or nurse to correlate the employee's medical conditions with the potential workplace hazards [8,94,98]. This is crucial for early detection of an illness related to a particular type of work [8]. Workers can provide information on the hazards in their operations and play a role in the design of OHP [8,96,98,101-105].

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