Exposure to Wood Dust and Health Effects: A Review of Epidemiological Evidences from Developing Countries

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In this paper, biomedical literature assessing the risks of nasal cancer and other wood dust exposure related symptoms and diseases in the developing world were reviewed in detail and contrasted with experiences in the developed world. Pollutants arising from industrial processes, including wood processing plants are amongst the leading causes of morbidity and premature deaths in exposed individuals. Industrial and artisanal wood processes are associated with emissions of varied sizes of wood dust particles, toxic chemicals and biological agents including fungi and endotoxins. To identify studies that assessed the risk of nasal cancer and decreased lung functions in wood industry workers; systematic literature reviews were conducted with scholarly search engines including PubMed, and Scopus. A total of 100 studies published after 1999 were scoped and identified in line with the objectives of the present review. The strongest associations between wood dust exposure and ill-health in developing world are: respiratory symptoms, (100%, n= 33) and an increased risk of nasal cancer (17%, n= 14). While, only 8% of the studies in developed world have associated wood dust exposure with nasal cancer, there is a great debate regarding the validity of such studies as their findings are limited to one sector of wood industries, sawmilling and lack basis of true toxicological studies. To confirm the aetiology of nasal cancer in wood industries, future studies should incorporate dose response relationship and potential implications of fine and ultrafine wood particles as well as endotoxins. This could aid to develop sustainable strategies for interventions and reduction of risk of exposure.

Keywords: Developing world, health effects, nasal cancer, wood dust, wood processing industries

1. Introduction

Pollutants arising from industrial processes, including wood industries are amongst the leading causes of morbidity and premature death in exposed individuals (Driscoll *et al*. 2005; Lopez *et al*. 2006). Industrial and artisanal wood processes are associated with emissions of varied sizes of wood dust particles and biological agents including fungi, bacteria and endotoxins (Saejiw *et al*. 2017; Mazzoli & Favoni 2012). Wood dust is one of the most common occupational carcinogens of modern era and is produced in a variety of wood operations including grinding, sanding, cutting, milling and debarking (IARC, 1995; Labrèche *et al*. 2013).

In general, exposure to wood dust has been associated with high prevalence of respiratory symptoms and diseases including irritations of the mucous membranes and nasal airways, chronic and acute deterioration of lung functions, asthma and allergies (Douwes *et al*. 2010; Estlander *et al*. 2001). Additionally, wood dust is also associated with exposure to pathogenic microorganisms such as fungi and bacteria, and is said to increase the risk of nasal cancer in most exposed individuals (Baran & Teul 2007; Lange 2008). In particular, cancer is the pathology at the centre of scientific researches in developed and developing world (Helmet *et al*. 2004; Labrèche *et al*. 2013).

However, it is hypothesized that there exist differing opinions from scholars on the potential to develop nasal cancer as result of exposure to wood dust, hence the development of this study. This paper primarily reviews published literature on exposure to wood dust and association with nasal cancer and other health ailments. Additionally, although South Africa accounts for some of the largest wood processing industries on the continent, including the paper manufacturing industry, it is also hypothesised that there is no published scientific information on exposure to wood dust and emerging ill-health.

2. Methodology

2.1 Data Collection

A systematic literature survey was conducted to identify studies assessing the risk of developing ill-health from exposure to wood dust. Online searches from various scholarly research engines including Google Scholar, Wiley Online, Scopus, ScienceDirect, PubMed were performed for datasets compilation in relation with specific keywords and objectives of the study (Moher *et al*. 2009). This was supplemented with bibliographic information of all selected studies.

2.2 Data Analysis and Exclusion criteria

Exposures were categorized according to types of wood processing industries and included: sawmills; furniture; joinery; carpentry; logging; pulp and paper; soft and hard wood manufacturing; as well as cabinet making industries. This classification is based on the International Association for Research on Cancer (IARC) classification guidance for occupational agents, mixtures and exposure circumstances involving the nasal cavity and parasinuses organs (Siemiatycki *et al*. 2004; Binazzi *et al*. 2015).

Additionally, studies were eligible for inclusion when they complied with the following criteria: i) studies involving adult workers in wood processing industries; ii) articles written in English and published in peer-reviewed journals or conferences; iii) epidemiological studies published after 1999 with either of case control, cross-sectional or longitudinal studies referring to occupational exposures to wood dust with potentials for nasal cancer and respiratory symptoms and lung changes. Consequently, excluded studies comprised of all review studies or personal opinion-oriented studies; studies published before 1999; studies examining simulation between occupational exposures other than wood dust and nasal cancer or respiratory symptoms.

Furthermore, the quality of included studies was assessed using the Newcastle-Ottawa Scale. This scale uses two different analytical tools for case control and cohort studies and comprises of three parameters which assess the quality of studies by points assignments. Four (4) maximal points are attributed for selection parameters; 2 for comparability and 3 for exposure outcome. In the end studies with a combined total of 7 points or more made the list were reported in this paper.

3. Results

In total 287 articles were initially retrieved from online search engines previously delineated. After a thorough consideration of selection criteria, 187 articles were excluded, 100 were reviewed in line with the objectives of this paper, and 67 were included in the final reviews. These studies were categorized according to country grouping (developing and developed) and health outcome (respiratory symptoms or diseases and nasal cancer). Table 1. gives a summary of studies according to country and health outcome.

Table 1. Summary of Studies according to Country Groups and Health Outcome

Country groups	Health outcomes		
	Respiratory Symptoms	***Asthma***	***Nasal Cancer***
Developed Coutries	33	29	12
Developing Countries	13	21	17

Following the countries grouping model used in this paper, developed countries consisted of the United States of America, Canada, Australia, the United Kingdom, France and Italy, while the rest of countries in the Americas, Eurasia, Africa and rest of the world made the list of developing countries.

3.1 Respiratory Symptoms and Asthma

The search identified a combined 33 (n= 33) studies from developing countries, and 13 studies from developed countries that assessed the relationships between wood dust and respiratory symptoms excluding asthma. Studies that reported on the prevalence of respiratory symptoms varied in terms of mythologies and design structures and included surveys (questionnaire), clinical trials, and control cases. Cough was the only respiratory symptom of the upper respiratory tract and was reported an incident rate of 100% across both country groups (Jacobsen *et al*. 2009; Tobin *et al*. 2016; Pramanik & Chaudhury, 2013; Lofstedt *et al*. 2017).

On the other hand, the symptoms of the lower respiratory tract were wheeze, chest pains and/ or chest tightness. These symptoms were reported in survey-based studies as well as case controls with incident rates of 60% and 27% in developing and developed countries respectively (Das *et al*. 2013; Kalliny *et al*. 2008; Rosenberg *et al*. 2002; Milanowski *et al*. 2002). However, in most studies that included clinical reports, frequencies of cough, chest pain and wheeze decreased at a rate of 20% for developing countries and 3.6% for developed countries (Das *et al*. 2013; Kalliny *et al*. 2008; Skovsted *et al*. 2003).

In addition, another symptom which was reported throughout the different studies was breathe shortness. This symptom was usually associated with high incident rate of chest tightness and wheeze (Krawczyk-szulc *et al*. 2014). Studies conducted in the United Kingdom and Australia found high prevalence of shortness of breath (42%) in workers already predisposed to cough and approximately 67% in Indonesia and Pakistan (Zaman *et al*. 2015; Meo 2006).

Moreover, health symptoms were also linked to dose response relationships. However, scholars had differing opinions on the relationship between concentration of dust particles and health outcomes. For instance in Mandryk *et al*. (1999) and Mandryk *et al.* (2001b) higher dust concentrations were associated with increased health symptoms. But a study by Rongo *et al.* (2004) found no association between dust concentration and increased health symptoms. Thus, it was concluded that rather than concentration of dust particles, worker's health condition could possibly influence he or she responds to exposure (Rongo *et al.* 2004).

In addition to the above, specific studies examined the prevalence of asthma in exposed individuals by diagnosis, surveys and case controls. The most frequently reported occurrence of asthma was in developing world (82%), and 65% in developed world (Black *et al*. 2006; Hameed *et al*. 2000). Fifty one percent (51%) of case controls associated sawmilling, carpentry and furniture with high prevalence of asthma in comparison to 30% in paper working (Kauppinen *et al*. 2006; Black *et al*. 2006; Kim *et al*. 2012; Tian *et al*. 2007). In a study by Alwis *et al*. (1999) it was highlighted that exposures bellow the recommended occupational exposure limits (OEL's) of 5 mgm^{-3} taken over an 8-hour working period had low incidence of injuries amongst individual workers, thus supporting the idea that dose response relationship plays a key role in the exacerbation of asthma effects (Douwes *et al*. 2001; Osman & Pakala, 2009).

Finally, there were other health symptoms such as irritations of the mucous membranes and the nasopharyngeal cavity. But these symptoms were inconstantly defined across the studies, and reported in less than 15% of all studies (Hlásková *et al*. 2015; Rosenberg *et al*. 2002).

3.2 Nasal Cancer

Association between wood dust exposure and development of nasal cancer is a well-documented phenomenon worldwide. However, in contrast to other health outcomes, the proportion of nasal cancer among wood industries' workers is hugely differing across reviewed studies. In developed countries, only a handful of studies have associated wood dust with nasal cancer, making just 8% of the 67 studies reviewed; whereas an approximate 17% in developing world evidenced increased likelihood of nasal and lung cancer. For example, Bornholdt *et al*. (2008) studied the risk of nasal cancer in variant wood industries. The exposure species included the hard and soft wood. Upon completion of case controls, they found that exposure to wood dust was associated with 21-fold increased risk of nasal cancer, but only in sawmilling. A study by Jayaprakash *et al*. (2008) comprising of mixed methods including personal surveys and clinical diagnoses, found 32% of increased risk nasal cancer among male workers in the United States. However, extensive reviews showed that these studies lacked one of the essential elements of toxicology—dose-response relationship was not included. Table 3 presents studies that examined the relationship between wood dust exposure and cancer.

Additionally, case controls by (Bhatti *et al*. 2011) also found increased risk of nasal cancer in sawmill (95%) but high decrease in the remaining of wood occupations. Similar evidences were found in studies in the pulp and paper industries, carpentry and furniture. In these industries, soft woods were the main species used to produce essentials. However, as it was the case with previously reported scientific evidences, lack of dose response relationship was noteworthy (Vallières *et al*. 2015; Andersson *et al*. 2013; Innos *et al*. 2000). Following such findings, scholars recommended that search on the aetiology of nasal cancer in wood occupations focus on hardwood, endotoxins or other rare by-products of wood processes such as bioaerosols (Oppliger *et al*. 2005).

Table III. Summary of Studies Analysing Relationships between Wood Dust and Cancer

Specific Studies on nasal cancer	**Study Outcome**	**Dose-response**
Cistero Bahima *et al.* 2000	Positive	Not included
Bahia *et al*. 2005	Posive	Not included
Wultsch *et al.* 2015	Negative	Included
D'Errico *et al.* 2009	Positive	Unclear
Greiser *et al.* 2012	Postive	Not included
Bhatti *et al.* 2011	Negative	Included
Vallières *et al.* 2015	Negative	Not included
Vaughan *et al.* 2000	Negative	Included
Pesch *et al.* 2008	Negative	Included
Jayaprakash *et al.* 2008	Positive	Not included
Emanuelli *et al.* 2016	Positive	Not included
Siew *et al.* 2012	Positive	Not included
Bornholdt *et al.* 2008	Posive	Included
Andersson *et al.* 2013	Negative	Not included
Innos *et al.* 2000	Negative	Not included
Barcenas *et al.* 2005	Positive	Unclear
Määttä *et al.* 2006	Postive	Not included

Specific Studies on nasal cancer	Study Outcome	Dose-response
Mensi *et al.* 2013	Postive	Unclear

Moreover, in studying the relationship between wood dust and nasal cancer, scholars also studied the ability of inhaled wood dusts to cause injuries to specific lung cells deoxyribonucleic acid (DNA). It is believed that the mechanisms of DNA injuries by either of hard or soft wood species could also be important in understanding the carcinogenesis of wood dust of any other by-products of wood processes (Pylkkanen *et al*. 2009; Pukkala *et al*. 2009). Consequently, toxicological studies based on this model have evolved. While some of these studies have found the evidence of cancer by DNA injuries and proposed mechanisms for exposure control (Siew *et al*. 2012; Määttä *et al*. 2006; Bornholdt *et al*. 2007;Barcenas *et al*. 2005; D'Errico *et al*. 2009; Emanuelli *et al*. 2016), some others could establish this relationship (Innos *et al.* 2000; Andersson *et al.* 2013; Pesch *et al.* 2008).

On the other hand, most studies on endotoxins inhalation in the wood industries have found close association between these intrusive bodies and cancer. However, these studies give limited specifications about the types of endotoxins, and often lack information on the nature and mode of development of nasal malignancy. Therefore, it cannot be said with certitude that wood endotoxins would lead to nasal cancer (Davies & Demers, 2012; Douwes *et al*. 2001; Mandryk *et al*. 2001a, 2001b). Furthermore, there is no published information in modern literature on the health effects of wood dust exposure in South Africa. However, the country poses some of the largest wood processing plants on the continent, including the paper industry (Pogue *et al*. 2008).

4. Discussion

Exposures to wood dust are highly associated with increased risk of several health effects. The studies that were reviewed in this paper showed that wood dust exposure increases the risk of a variety respiratory symptoms in individual workers. Thirty-three studies focusing on developing countries showed that cough is the most prevalent of all respiratory symptoms. This was equally reported in the developed countries. It was also reported that increased exposure to wood dust aggravate the risk of chest tightness and wheeze.

In many industrial surveys, the frequency occurrence of wheeze and chest tightness was highly distributed. Few studies where medical diagnosis was included established links between survey data and clinical reports. In those studies, the incidences of respiratory symptoms decreased by 7% in developed countries and 11% in developing countries (Siew *et al*. 2012; Thetkathuek *et al*. 2016; Jayaprakash *et al*. 2008; Osman & Pala 2009).

Additionally, the study by Rongo *et al*. (2004) established that dose-response relationship does not necessarily play a role on the aggravation of respiratory symptoms, although other studies had initially established such relationships (Meo, 2004; Vivi Schlünssen *et al*. 2008; Jacobsen *et al.* 2009; Akinyeye *et al*. 2013). However, Rongo *et al*. (2004) discussed that the role of other existing ill symptoms such as bronchitis in aggravating the health outcomes in exposed individuals. Moreover, variations were found in terms of occupational asthma across the study groups. Workers in developing countries had high incidence of occupational exposures than those in developed countries. But asthma was prevalent in all wood occupations where exposure concentrations were expressed above the OEL of 5 mgm^{-3}.

Exposure to wood dust was also associated with the risk of nasal cancer. However, strong associations were strictly limited to few of the reviewed studies, mostly focusing on sawmill processes. Certain studies in developing countries associated exposure to hard wood dust with cancer, whereas others established a low to moderate risk with soft wood species. However, paradox findings were found in few case control studies conducted in Canada, the USA and the United Kingdom. Findings suggested that neither solid wood dust, nor soft wood dust can increase the risk of cancer (Vaughan *et al.* 2000; Bhatti *et al.* 2011).

Furthermore, most studies did not include dose response relationships as noted in Table 2, whereas other studies where it was included there was still no evidence of nasal cancer (Pesch *et al.* 2008; Vaughan *et al.* 2000). In other studies, it was not clear weather dose response relationship was included, but scholars either based their conclusions on studies by other scholars, rejected or supported the carcinogenesis of wood dust. Finally, Mandryk *et al*. (2001a) highlighted that endotoxins could be playing a role in the development of nasal cancer in wood industries. This was evident of Szymczak & Szadkowska-Stańczyk, (2004) in Poland.

5. Conclusion

Despite compelling associations between wood dust and health effects including nasal cancer, there is inconsistency in studies reviewed, particularly on the aetiology of nasal cancer in the wood industry. In essence, reviewed studies evidenced moderate risk of nasal cancer from exposure to wood dust but with little or non-existing reports on exposure dosage. This element is important, especially when reporting on toxicological findings. In conclusion, this paper does not erase information on the degree of carcinogenesis of wood dust, but it is suggested that future studies exploring the aetiology of nasal cancer in wood industries, focus on fine and ultrafine wood particles as well as endotoxins. It is also important that future studies incorporate all fundamental elements of toxicology including dose-response relationship to help establish whether there is an association between cancer incidences in wood industries and exposure to wood dust or other particles emitted during wood processing. This could give a clear guidance for the development of any interventions strategies and the reduction of exposure risk.

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