WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY

By

Paulino Samuel Chamba

Thesis presented for the degree of

Doctor of Philosophy

in the School of Public Health and Family Medicine

University of Cape Town

December 2020

WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY

By

Paulino Samuel Chamba

Thesis presented for the degree of

Doctor of Philosophy

in the School of Public Health and Family Medicine

University of Cape Town

Supervisor: Professor Mohamed Fareed Jeebhay

Co-supervisor: Dr Roslynn Baatjies

This thesis is presented in fulfilment of the requirements for the degree of Doctor of Philosophy (PhD) in the School of Public Health and Family Medicine, Faculty of Health Sciences, University of Cape Town. The work on which this thesis is based is original research and has not, in whole or in part, been submitted for another degree at this or any other university. The contents of this thesis are entirely the work of the candidate.

Signed by candidate

Paulino Samuel Chamba

17 December 2020

ABSTRACT

Background: Workers in the wood processing industry are exposed to a heterogeneous mixture of inorganic and organic particles comprising wood fragments, viable and non-viable microorganisms, endotoxins, glucans and allergens, with the potential to cause work-related asthma. While this association has been reported in diverse settings, few studies have comprehensively studied host and environmental risk factors for work-related asthma phenotypes associated with wood dust. The aim of this study was to determine the prevalence and risk factors for work-related asthma among workers in the Mozambiquan wood processing industry.

Methods: A cross-sectional study of wood workers was conducted in 21 factories located in three Mozambiquan provinces that processed various indigenous wood species. The environmental exposure assessment component comprised systematic walk-through inspections of all factories and the measurement of inhalable wood dust to determine particulate, (1-3)-β-D-glucan and endotoxin concentrations. A random sample of 30 workers were selected from similarly exposed groups (EGs) working in 9 representative factories for personal environmental sampling using PAS-6 sampling heads connected to Gillian GilAir pumps. A total of 124 of personal inhalable dust samples were collected for analysis. For the health outcome assessment, 450 subjects completed an ECRHS questionnaire adapted for occupational studies and underwent spirometry accompanied with bronchial reversibility and fractional exhaled nitric oxide (FeNO) testing conducted during the work shift. In addition, sera were obtained to determine the atopic status of workers using the Phadiatop test. Multivariate multiple lean and logistic regression was conducted adjusting for known confounders in saturated models using STATA 12 computer software.

Results: The environmental exposure assessment demonstrated that the mean inhalable concentrations were 3.29 mg/m^3 (GSD: 3.04) dust particulate, 98 endotoxin units (EU)/m^3 (GSD: 5.05) and 123 ng/m^3 (1-3)-β-D-Glucans (GSD: 5.05). These concentrations are higher compared to international exposure standards, generally ranging between 0.5-5 mg/m^3 for dust particulate and 90 EU/m^3 for endotoxins. A significant ($p<0.05$) modest correlation was observed between dust particulate and endotoxin (Pearson r = 0.48) and glucan (r = 0.40) concentrations. In the multivariate models, certain wood species were significantly associated with increased inhalable dust particulate levels - mahogany bean (*Afzelia quanzensis Welw*) (GM ratio=3.39) and African sandalwood (*Spirostachys Africana Sonder*) (GM ratio=3.19), as was factory building features (closed and semi-closed buildings, GM ratio=2.14). Additional determinants of elevated endotoxin exposures included African sandalwood (GM ratio=9.21) and working in closed buildings (GM ratio=2.10), while working in semi-closed buildings (GM ratio=2.14) was the main determinant of elevated glucan levels. Damp cloth cleaning methods were associated with lower dust particulate (GM ratio=0.55), endotoxin (GM ratio=0.32) and glucan (GM ratio=0.53) levels. The health outcome assessment of study subjects found the mean age to be 38 years, mostly male (94%), a large proportion non-smokers (76%) and 50% were atopic. The prevalence of current asthma was 7%, with equal proportions of atopic and non-atopic asthma (4%), while 2% had work-related asthma. The main host factors associated with work-related asthma outcomes were age, gender and atopic status. Exposure to Missanda (*Erythrophleum suaveolens Brenan*), Panga-panga (*Millettia Stuhlmannii Taub.*) and Mahogany bean (*Afzelia quanzensis Welw.*) wood species was associated with work-related ocular-nasal symptoms, while Mutondo (*Cordyla Africana*) species was associated with both work-related ocular-nasal and asthma symptoms. Work-related ocular-nasal symptoms were also associated, in a dose-dependent manner, with EGs categorized according to job titles as well as current dust particulate levels (medium, 4.68-4.71 mg/m^3: OR = 3.45, 95% CI: 1.21 – 10.63; high, >4.71 mg/m^3: OR = 3.66, 95% CI: 1.19 – 11.26) when compared to the low EG (<4.68 mg/m^3) in unadjusted models. A similar trend was observed in the multivariate models adjusted for age, gender and smoking status. A history of work-related asthma symptoms was also positively associated with mean cumulative dust particulate exposure calculated across all jobs in the factory (OR = 1.01, 95% CI: 1.00 – 1.02) in multivariate linear regression models. In both unadjusted and adjusted models, increasing degree of bronchial reversibility was associated with increasing current dust particulate levels (medium, 4.68-4.71 mg/m^3: OR = 1.99, 95% CI: 1.25 – 3.22; high, >4.71 mg/m^3: OR = 1.73, 95% CI: 1.07 – 2.80) when compared to the low EG (<4.68 mg/m^3). Increasing FeNO was associated with cumulative dust exposure quartiles based on current job >10.09 mg/m^3-yr in both unadjusted (Q2, OR = 1.23, 95% CI: 1.02 – 1.51; Q3, OR: = 1.11, 95% CI: 0.91 – 1.35, Q4, OR= 1.23, 95% CI: 1.02 – 1.49) and adjusted models.

Conclusion: This study demonstrated that exposure to all wood dust components in Mozambiquan wood processing workers were above international standards. The 7% asthma prevalence is consistent with global and specifically African country estimates, while 2% had work-related asthma. Processing of particular indigenous wood species and exposure metrics based on current as well as cumulative inhalable wood dust exposures were associated with an increased risk of work-related ocular-nasal and asthma symptoms, bronchial reversibility and airway inflammation. These risks are modified by host-associated factors of age, gender and atopy.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor Professor Mohamed Jeebhay (Occupational Medicine Division, School of Public Health and Family Medicine, University of Cape Town) and my co-supervisor Dr Roslynn Baatjies (University of Cape Town and Cape Peninsula University of Technology) for their insights, guidance, patience and support throughout this project.

I would like to express my sincere appreciation to the following people who have contributed to the successful completion of this thesis:

Associate Professor Elizabete Nunes (Faculty of Medicine, Eduardo Mondlane University) and Dr Custodio Muianga (CDC/Agency for Toxic Substances and Disease Registry, USA) for their encouragement to apply for the Fogarty PhD scholarship and their inputs during the conceptualisation of the study.

Prof.Thomas Robins (Occupational and Environmental Medicine Specialist, University of Michigan, USA) for his inputs in the early stages of protocol design.

Associate Professor Antonio Cumbane (Department of Chemical Engineering of Eduardo Mondlane University) for his assistance during the exposure assessment part of study.

Dr. Tanusha Singh (National Institute for Occupational Health, South Africa) for conducting laboratory analysis of samples for endotoxins and glucans.

Dr. Sabine Kespohl (Institute for Prevention and Occupational Medicine of the German Social Accident Insurance, Germany) for conducting preliminary immunoassays assays on certain Mozambiquan wood species and the sera of index cases patients with work-related asthma.

Dr. Alberto Manhiça (Department of Forestry Engineering of Eduardo Mondlane University) for his assistance with the scientific nomenclature of the various wood species.

Workers and management from all participating factories for their collaboration.

Fieldworkers, Daniel Alficha, Inácio Luis Braz, Dorca Luís, Guilherme Tomo, Nelto Luís, Ana Paula Mafesse, João Avelino Samaja, Matias Veniz Chambuca, Manuel Chamba, Elias Chamba, Lito Cuamba and Albino Magaia for for their assistance with the fieldwork as well as the data coding and management.

Faranaaz Bennett, Sharon Ferguson and Carmen De Koker (School of Public Health and Family Medicine, University of Cape Town) for their support on administrative issues.

Funding support from the Fogarty International Center / University of Michigan Millennium Promise Programme doctoral scholarship for research training in environmental and occupational lung diseases as well as support from the Ministry of Health of Mozambique.

Finally, I wish to thank my loving wife, Clementina Motiane, and our children, Edilson, Damasio, Clayton and Nellywin for their unconditional love, unwavering support and encouragement throughout this long journey.

PREFACE

The following scientific paper was published during the doctoral research period:

- **Chamba P**, Nunes E. Work-related asthma among workers in the wood-processing industry: A review. Curr Allergy Clin Immunol. 2016;29(2):110–7 (Appendix 12).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIXES

LIST OF ABBREVIATIONS

ACGIH: American Conference of Governmental Industrial Hygienists

AM: African Mahogany

AM: arithmetic mean

AS: African sandalwood

ASS: asthma symptom scores

AT: African Teak

ATS: American Thoracic Society

BAL: bronchoalveolar lavage

BDR: bronchodilator response

BEAS-2B: human bronchial epithelial cells

BHR: bronchial hyper-responsiveness

BMI: body mass index

CCA: chromated copper arsenate

CI: confidence interval

COPD: chronic obstructive pulmonary disease

CS: chi-square

ECRHS: European Community Respiratory Health Survey

EG: exposure group

ERS: European Respiratory Society

EU: endotoxin unit

$FEF_{25-75\%}$: forced expiratory flow at 25-75%

FeNO (ln): fractional exhaled nitric oxide (natural log)

FeNO: fractional exhaled nitric oxide

FEV_1: forced expiratory volume in one second

FVC: forced vital capacity

GEE: generalised estimation equation

GLI-2012: Global lung function initiative 2012

GLM: generalised linear models

GM ratio: geometric mean ratio

GM: geometric mean

GSD: geometric standard deviation

GWAS: genome-wide association studies

HGJM: Hospital Geral Jose Macamo

HLA: human leukocyte antigen

HREC: Human Research Ethics Committee

ICOH: International Commission on Occupational Health

IgE: immunoglobulin E

IL-1: interleukin-1

INE: Instituto Nacional de Estatistica

IQR: interquartile range

ISO: International Organization for Standardization

L: litres

LAL: limulus amebocyte lysate

LEV: local exhaust ventilation

LIW: Lebombo Iron Wood

LLN: lower limit of normal

LOD: limit of detection

MB: Mahogany bean

MR: mean ratio

MS: Missanda

MSS: Messassa

MT: Mutondo

MTA: material transfer agreement

NC: not calculable

NIOSH: National Institute for Occupational Safety and Health

NSBH: nonspecific bronchial hyperresponsiveness

OEL: occupational exposure limit

OHS: occupational health and safety

OR: odds ratio

OSHA: Occupational Safety and Health Administration

P: Pine

PBD: post-bronchodilator

PEF: peak expiratory flow

PP: Panga-panga

ppb: parts per billion

PPE: personal protective equipment

Ppm: parts per million

DECOS: Dutch Expert Committee on Occupational Safety

Q: quartile

ROS: reactive oxygen species

RR: relative risk

RSA – Republic of South Africa

SANAS: South African National Accreditation System

SE: standard error

SEG: similarly exposed groups

sIgE: specific immunoglobulin E

STEL: short-term exposure limit

TDI: toluene diisocyanate

TWA: time-weighted average

UCT: University of Cape Town

USA: United States of America

WRA: work-related asthma

WRAS: work-related asthma symptoms

WRONS: work-related ocular-nasal symptoms

ZW: Zebrawood

CHAPTER 1

INTRODUCTION

1.1. INTRODUCTION

Globally, wood is one of the most important renewable resources and extends over approximately one-third of the earth's total landmass: about 3.4 million km^2(1). Worldwide 12,000 tree species exist, and more than 1000 of these are used for commercial purposes (2). In Mozambique 118 wood species have been identified and classified according to various criteria including its commercial, scientific, rarity, usefulness, strength and quality. These are grouped into five major categories, with 9 classified as precious or high commercial value, 21 as first class, 21 as second class, 40 third class and 27 species classified as fourth class (3, 4). These wood species, which are of high commercial value, are processed further by wood workers in the country.

The most commonly processed wood species in Mozambique include: Mahogany bean (*Afzelia quanzensis Welw.*), African teak (*Pterocarpus angolensis DC*), Panga-panga (*Millettia Stuhlmannii Taub*), Lebombo ironwood (*Androstacys johnsonii Prain*), African mahogany (*Khaya nyasica Stapf*), African sandalwood *(Spirostachys Africana Sonder*), Pine (*Pinus sp*), Mutondo (*Cordyla Africana*), Zebrawood (*Microberlinia brazzavillensis*), Missanda (*Erythrophleum suaveolens Brenan*), Messassa (*Brachystegia spiciformis Benth.*), Pau-rosa (*Berchemia zeyheri (Klotzch) Hemsley*), Mugonha (*Breonadia microcephala Ridsd.*), Mucarala (*Burkea africana Hook.*), Ntholo (*Pseudolachnostylis maprouneifolia Pax*), Mondzo (*Combretum imberbe Wawra.*), Chacate (*Guibourita conjugate (Bolle) J.Leonard*), Ncula (*Pterocarpus tinctorious Welw.*), Metacha (*Berchemia discolour (Klotzsch) Hemsley*), Mepepe (*Albizia adianthifolia W.F.Wight*), Ebano (*Dyospiros mespiliformis Hochst.*) and Medium-density fibreboard (*MDF*). All the woods processed in these factories and listed above are hardwood, with the exception of pine which is a softwood and Medium-density fibreboard which is an engineered wood product made by breaking down hardwood or softwood residuals into wood fibres.

The National Institute of Statistics (INE) (2017) estimated that at least 9.807 people were employed in 787 companies in Mozambique in the formal sector (5). The number of workers and companies in the informal sector is not captured by the INE estimates and is unknown, but it is likely to be higher than the formal sector. The distribution of workers and wood processing companies in Mozambique is presented in Table 1.1. Mozambique is a country with extensive forestry resources (6) and there is a trend for the number of wood processing companies and consequently the number of workers to increase year on year (7).

Table 1.1: Mozambiquan wood processing companies formally registered and number of workers employed per province

No.	Province	No. of factories	No. of workers
1	Niassa	23	93
2	Cabo Delgado	48	921
3	Nampula	52	490
4	Zambezia	133	1,059
5	Tete	38	782
6	Manica	43	904
7	Sofala	106	1814
8	Inhambane	95	603
9	Gaza	65	447
10	Maputo Province	62	720
11	Maputo City	122	1974
Total		787	9,861

Source: INE (2017). Note: Wood processing companies include furniture, joinery and sawmills

Various studies, including some in Africa, have reported an association between occupational exposure to wood dust and asthma-related outcomes. Globally, the prevalence of asthma in woodworkers is between 5.6% and 18%, while in Africa it is between 3% and 7% (8-11). While the prevalence of ocular-nasal symptoms in African settings vary between 30% and 78% (12,13), his range is much lower (13% - 34%) beyond the African continent (14-18). To date, there is no published data on work-related asthma disease burden among workers exposed to wood dust in Mozambique.

The findings of a pilot study of wood processing workers in Mozambique demonstrated high exposures to wood dust, with an average of 11.2 mg/m^3 [range 0.4 – 36.7 mg/m^3]. These levels were well above the international standards (0.5 – 5mg/m^3). Furthermore, in this study of 120 workers, a high prevalence of nasal symptoms (52.4 %), shortness of breath (47.6%), cough (44.4%), early morning phlegm (42.9%), wheezing or whistling (15.9%) were reported (19). The findings of this study highlighted the need for a more detailed investigation to better understand the determinants of wood dust exposures emanating from indigenous exoctic wood and the adverse respiratory health outcomes. The results of the study will be used to design a prevention and control strategy for wood dust exposure among workers at increased risk of work-related respiratory disease in the timber, lumbar and wood processing industry. Furthermore, the study results will also highlight the need for appropriate exposure standards to prevent work-related asthma in Mozambiquan wood processing workers.

1.2. STUDY AIM

To determine prevalence and risk factors for asthma phenotypes including work-related asthma and rhinitis, among workers in the Mozambique wood processing industry.

1.3. OBJECTIVES OF THE STUDY

a) To characterise exposure to inhalable wood dust particulate, endotoxins and (1-3)-β-D-glucans and their determinants (wood species, building characteristics, work processes and control measures) among workers in the Mozambique wood processing industry.
b) To determine the prevalence of work-related respiratory symptoms, allergic sensitisation, lung function impairment and the determinants of elevated fractional exhaled nitric oxide (FeNO) among workers in the Mozambique wood processing industry.
c) To determine the host and self-reported environmental risk factors associated with work-related respiratory symptoms, airway obstruction, bronchial reversibility and FeNO among wood processing workers in Mozambique.
d) To explore the nature of exposure-response relationships for work-related respiratorysymptoms, airway obstruction, bronchial hyperresponsiveness and FeNO among workers in the Mozambique wood processing industry.

1.4. STRUCTURE OF THE THESIS

Chapter 1: Introduction, aim, objectives and outline of the thesis

This chapter provides a brief introduction to the Mozambique wood processing industry and reports on the estimated burden of occupational asthma among workers exposed to wood dust in general and for Africa in particular. This is followed by a brief description of the aim, objectives and structures of the thesis.

Chapter 2: Literature review

The chapter 2 presents a review of the literature focussing on the constituents of wood and wood dust, the epidemiology of allergic sensitization and asthma associated with wood dust, exposure and causative agents, health outcomes and pathophysiological mechanisms of asthma associated with wood dust, risk factors (environmental and host factors) and modifiers (including dose-response relationships). Finally, it discusses preventive measures for asthma associated with wood dust exposure**.**

Chapter 3: Methods

In this chapter the study design, population and sampling strategy for the environmental exposure and health outcome components is described. This chapter also describes the production process in the Mozambique wood processing industry and presents information on the study instruments used and how the human subjects and ethical issues have been addressed. Finally, more detail is provided on the data management and analysis plan, which include exposure assessment analysis, health outcomes – asthma phenotypes analysis, host and environmental risk factors for asthma outcome analysis, and exposure-response analysis.

Chapter 4: Characterisation of exposure to wood dust, endotoxins and glucans among workers in the Mozambique wood processing industry and their determinants

This chapter presents a comprehensive exposure assessment, which included measurement of wood dust particulate, glucans and endotoxins. Additionally, information was collected on location of the factories, exposure groups, job titles, type of woods species processed, state of woods used (dry, fresh or both), type of buildings (open, semi-closed or closed), building size, number of workers in factory, engineering controls, frequency of sharpening cutting tools, wood dust cleaning methods, frequency of cleaning surfaces and floors, cleaning working clothes, waste disposal methods, use of PPE and dust control training. Finally, the determinants of exposure to the three wood dust exposure parameters are presented using different modelling approaches.

Chapter 5: Respiratory symptoms, airway inflammation and lung function of workers in the Mozambique wood processing industry

This chapter presents the demographic characteristics of the study population, current job exposure characteristics, asthma history and related symptoms. This is followed by presentation of lung function indices, namely baseline spirometry and post-bronchodilator response results. This chapter also presents data on fractional exhaled nitric oxide (FeNO) results and the different asthma phenotypes observed.

Chapter 6: Environmental and host risk factors associated with various asthma-related outcomes among workers in the Mozambique wood processing industry

In this chapter, the self-reported environmental and host risk factors associated with work-related respiratory symptoms, airway obstruction, bronchial reversibility and FeNO among wood processing workers is explored using multivariate linear and logistic regression modelling techniques.

Chapter 7: Exposure-response relationships

This chapter reports on exposure-response relationships between inhalable wood dust particulate exposures and work-related asthma. It employs the use of multiple exposure metrics (current and cumulative exposure) in relation to clinical indices of asthma-related outcomes (work-related respiratory symptoms, airway obstruction, bronchial reversibility and FeNO).

Chapter 8: Summary of study findings, recommendations and conclusion

This chapter summarizes the main findings of the thesis in relation to: a) The exposure characterisation to wood dust, endotoxins and glucans among workers in the Mozambique wood processing industry and their determinants; b) The symptoms, allergic sensitisation profiles and lung function indices and asthma phenotypes observed; c) Host and self-reported environmental risk factors associated with asthma-related outcomes in woodworkers, e) Exposure-response relationships between inhalable wood dust particulate exposures and work-related asthma. The strengths and limitations are discussed, conclusions drawn and recommendations are made on workplace control measures, medical surveillance programs, and areas for future research in Mozambiquan wood processing workers.

1.5. REFERENCES

1. Meo SA. Effects of duration of exposure to wood dust on peak expiratory flow rate among workers in small scale wood industries. Int J Occup Med Environ Health. 2004;17(4):451–5.
2. Schluenssen V, Sigsgaard T, Raulf-Heimsoth M, Kespohl S. Workplace exposure to wood dust and the prevalence of wood-specific sensitization. Allergologie. 2012;35(8):402–12.
3. Fernandes A. Análise da produção de madeira para o fornecimento sustentável de energia doméstica aos centros urbanos de Moçambique. Universidade Federal do Paraná. 2014.
4. Conselho de Ministros. Regulamento da Lei de Florestas e Fauna Bravia. Bolentim da Repub Moçambique. 2002;I SERIE(22):25.
5. Instituto Nacional de Estatistica. Ficheiro de Unidades Estatísticas. 2017.
6. Marzoli A. Inventário Florestal Nacional, Relatório Final. 2007;109.
7. Castel-branco CN. Situação Económica em Moçambique : reavaliação da evidência com foco na dinâmica da produção industrial. 2003;1–22.
8. Alwis KU. Occupational exposure to wood dust. The University of Sydney. 1998.
9. Mandryk J, Alwis KU, Hocking AD. Effects of Personal Exposures on Pulmonary Function and Work-related Symptoms Among Sawmill Workers. Ann Occup Hyg. 2000;44(4):281–9.
10. Douwes J, McLean D, Slater T, Pearce N. Asthma and other respiratory symptoms in New Zealand pine processing sawmill workers. Am J Ind Med. 2001 Jun;39(6):608–15.
11. Ugheoke A. Prevalence of respiratory symptoms among sawmill workers in Benin City, Nigeria. Int J Trop Med. 2009;4(1):1–3.
12. Nde F, Mbatchou H. Respiratory Symptoms and Pulmonary Function tests among Informal Sector Workers Exposed to Wood Dust in Douala, Cameroon. J Allergy Ther. 2015;06(06):8–11.
13. Aguwa EN, Okeke TA, Asuzu MC. The prevalence of occupational asthma and rhinitis among woodworkers in south-eastern Nigeria. Tanzan Health Res Bull. 2007;9(1):52–5.
14. Wiggans RE, Sumner J, Robinson E. Respiratory symptoms, lung function and sensitisation across different exposure groups of British woodworkers. Thorax. 2017;72(3):A1-278.
15. Publio A. Prevalence of respiratory symptoms among furniture factory workers, in Votuporanga-SP. 2008.

16. Schlünssen V, Schaumburg I, Taudorf E, Mikkelsen AB, Sigsgaard T. Respiratory symptoms and lung function among Danish woodworkers. J Occup Environ Med. 2002;44(1):82–98.
17. Milanowski J. Work-related symptoms among furniture factory workers in Lublin Region (Eastern Poland). Ann Agric Environ Med. 2002;9:99–103.
18. Arbak P. Respiratory Symptoms and Peak Expiratory Flow Rates Among Furniture - Decoration Students. Ann Agric Env Med. 2004;(11):13–7.
19. Chamba P. Sintomas Respiratórios e Função Pulmonar nos trabalhadores de três empresas da Indústria Madeireira em duas cidades de Moçambique. Universidade Eduardo Mondlane; 2011.

CHAPTER 2

LITERATURE REVIEW

BACKGROUND AND REVIEW OF THE LITERATURE ON WORK-RELATED RHINITIS AND ASTHMA IN WOODWORKERS

2.1. Background

Various studies have demonstrated that workers in the wood processing industry are at increased risk of developing work-related asthma and rhinitis. This may be due to exposure to various agents that are either respiratory sensitizers or irritants such as wood fragments, viable and non-viable microorganisms, endotoxins, glucans and allergens, as well as other low molecular weight compounds (1-6). Exposure to wood dust particulate and associated agents present in wood dust has emerged as being of particular importance in wood processing settings. This is due to the extensive use of various woods, a number belonging to exotic wood species from various geographical contexts. In the past decade, a growing number of epidemiological studies have reported an increased risk of upper and lower respiratory symptoms including asthma associated with wood exposures in African settings (7-10). However, there no published studies that have investigated the role of exotic indigenous wood species in the Mozambiquan wood processing industry in development of work-related asthma and rhinitis.

Search strategy

The sources used to search relevant articles for the literature review included PubMed, Google and Embase. The following keywords were used: wood dust, woodworkers, wood processing industry, endotoxins, β-glucans, allergens, terpenes, asthma, occupational asthma, work-related asthma, fractional exhaled nitric oxide, spirometry, bronchial reversibility, exposure standards, determinants of exposure and control measures. Reference lists from the articles obtained were also screened for relevant publications. The selection of articles to be included in the review was not restricted to any time period. Exposure assessment studies, epidemiological studies, case reports and case series that investigated work-related asthma in wood processing workers in the last 20 years (2000 to 2020) were summarized.

Table 2.1: Airborne wood dust concentration in Mozambiquan workplaces surveyed in 2011

Personal Samples	N	Max (mg/m^3)	Min (mg/m^3)	Average (mg/m^3)	Reference range	Area Samples	N	Max (mg/m^3)	Min (mg/m^3)
Lhanguene Joinery	5	36.7	0.4	12.2	RSA: 5 mg/m^3 Sweden: 2mg/m^3 ACGIH: 0.5 mg/m^3 for western red cedar and 1mg/m^3 for all other species	Lhanguene Joinery	5	22.6	0.1
Secama Sawmill	2	16.0	4.8	10.4		Secama Joinery	3	4.4	0.9
Secama Machinery	2	6.1	3.1	4.6		Secama Machinery	2	0.8	0.5
Secama Joinery	1	0.4	-	0.4		Yola Sawmill	3	19.3	2.7
Yola Sawmill	3	34.9	2.9	18.6		Yola Joinery	2	0.9	0.2
Yola Joinery	2	27.3	8.4	17.8					
HGJM	5			0.9		HGJM	5		
Total	**20**						**20**		

N - Number of samples; Max – Maximum; Min – Minimum

Source: Chamba and Nunez (5)

2.2. WOOD PROCESSING

Wood is among the most important natural resources in the world and annually at least 1700 million per m^3 are collated for industrial use (6).

The major wood working processes are debarking, sawing, sanding, milling, lathing, drilling, veneer cutting, chipping and mechanical defibrating. From the tree felling stage onwards through the various stages of wood working and manufacturing processes, workers are exposed to airborne dust of different particle sizes, concentrations and compositions. Sawing and sanding both shatter lignified wood cells and break out whole cells and groups of cells (chips) (7) . The more cells shattering that occurs the finer the dust particles are produced. Sawing and milling are mixed cell shattering and chip forming processes, whereas sanding is almost exclusively cell shattering. In hardwoods, the cells are tightly bound resulting in more shattering and more dust. Similarly, dry wood leads to more dust formation. Softwood particles are more fibrous and usually larger and as a result less capable of becoming airborne (7).

Considerably high heat generation during sawing, machining and sanding may change the chemical composition of wood dust. It has been reported that hardwoods give rise to finer airborne dust at a lower rate during sanding than softwoods, but that the total amount of airborne dust produced depends mainly on the total mass of wood removed, and not the type of wood (7).

2.3. WOOD PRODUCTION AND PROCESSING IN THE MOZAMBIQUAN FURNITURE INDUSTRY

In general, wood processing in Mozambique comprises various steps as outlined in Figure 2.1- 2.5. Prior to processing the *front-end process* involves procuring wood at the forestry concession where it is cut into different sizes of blocks and slabs or purchased at the wood market. The freshly cut wood are seasoned or subjected to sun exposure in a courtyard or greenhouse. After seasoning the wood undergoes treatment with chromated copper arsenate (CCA). Prior to the commencement of *processing the wood* and manufacturing of any furniture product a desired design is selected. The seasoned wood blocks are cut into the desired shape and sliced according to the design requirements. Thereafter, the slices of wood are molded into the desired shape according to the design. Carving entails applying different patterns made in the wood. Once the different pieces are carved and molded, these parts/pieces are assembled or fixed together to give shape to the final product. The assembled product is ground to make the surface smooth, whereafter finishing material is applied to prepare the surface ready for paint or polish. Upholstery of fabric is carried out according to specifications of design. The *back-endprocess* involves workers employed in the cleaning workshops, locksmith, maintenance services, office, forestry management and wood machine repair.

Based on preliminary studies as well as other published studies (12, 13) workers manually planning, sawing and setting appear to have lower exposures, whereas workers drilling and planing with machines have higher exposures. Furthermore, workers involved with sawing and carving using machines, cleaning workshops and repairing the wood machines generally have even higher wood dust exposures.

Due to the damp consistency, fungal or bacterial contamination occurs on a large scale when green or fresh wood is processed.

Besides exposure to wood dust per se, wood workers are potentially exposed to various chemicals used in the different stages of the production process in the furniture industry, including glues (during assembling), dyes, solvents, dryers (in the finishing stage for painting), varnishes (in the finishing stage for polishing) and hardeners.

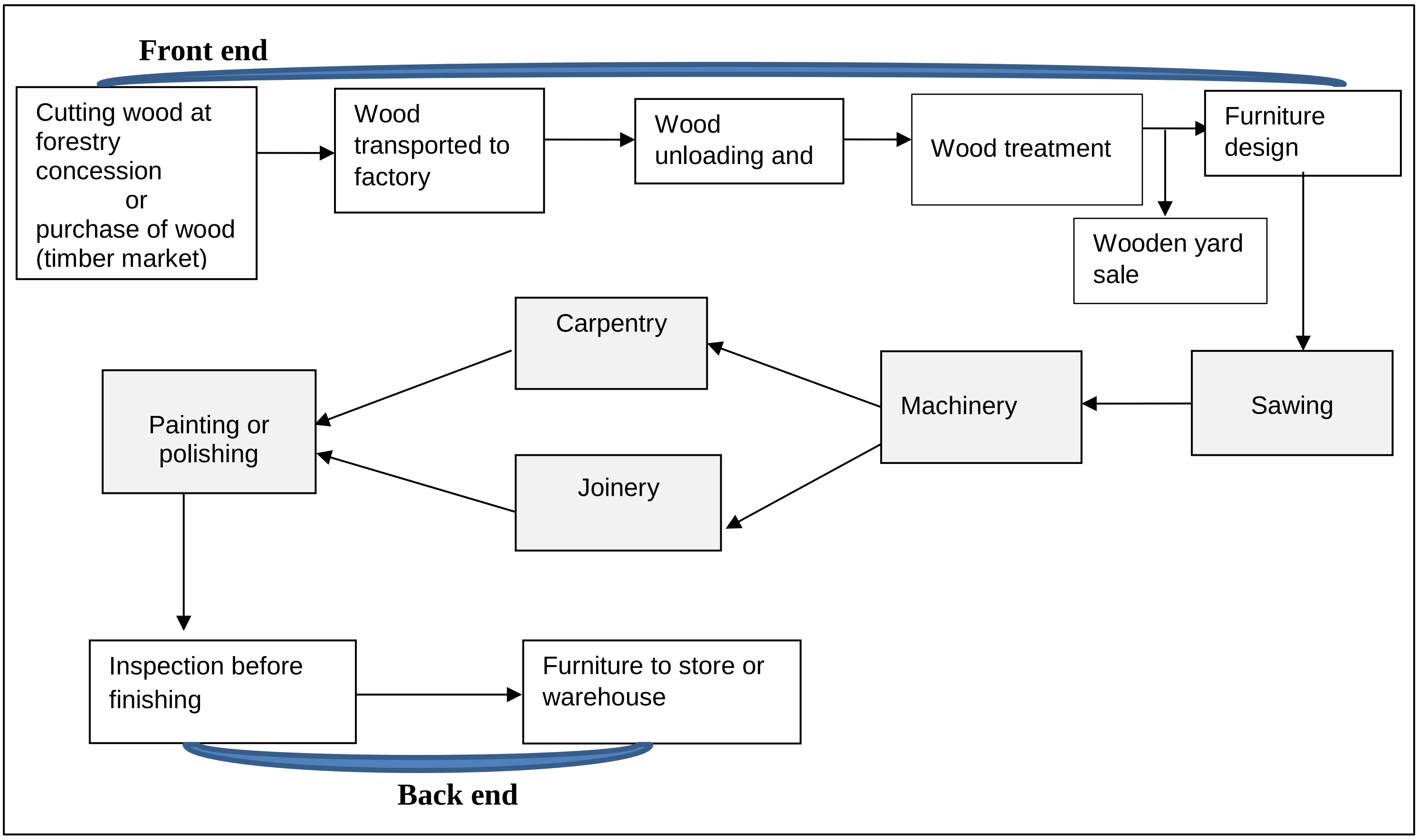
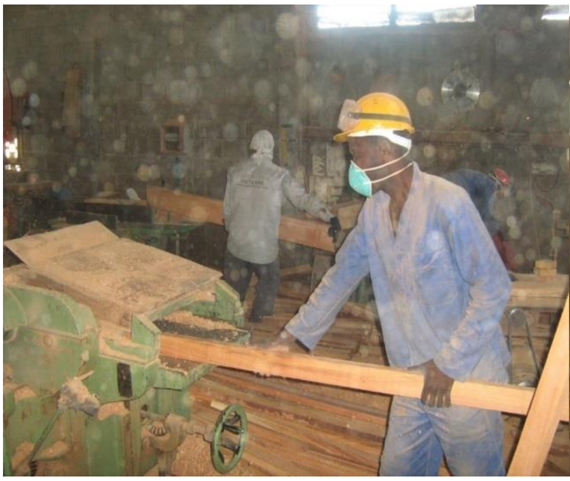


Figure 2.1: Diagram of typical furniture/joinery processing steps (adapted from Wooden Furniture Manufacturing Unit Unido.org)

Figure 2.2-2.5. Sources of high-risk wood dust exposure in Mozambiquan wood factories (Source**:** Work-related asthma among wood processing industry: A review" published on Journal of Current Allergy and Clinical Immunology, in 2016) (5).



1. Carving and sawing wood

2. Drilling operations

3. Planing wood

4. Machine cleaning

2.4. CONSTITUENTS OF WOOD AND WOOD DUST

Wood is the hard fibrous substance composed mostly of the stem and branches of a tree or shrub and covered by the bark. The inner core of the wood is referred to as heartwood and the outer layer is called sapwood. For industrial purposes, wood is classified into two types: hardwoods and softwoods. Softwoods are derived from coniferous trees (botanically named as *Gymnospermae* with exposed seeds), whereas hardwoods are from deciduous trees (botanically named as *Angiospermae* with encapsulated seeds) (7).

The major component (about 95 weight %) of wood is composed of cellulose, hemicellulose and lignin (9). Cellulose, which is built up exclusively of D-Glucose units joined by β (1->4) glycosidic linkages, is the major component (40-50%) of both hardwood and softwood. The proportion and chemical composition of lignin and polyoses differ in softwood and hardwood. Polyoses are present in larger amounts in hardwood than softwood and differ in their sugar composition. Softwood has a higher proportion of mannose and more galactose units than hardwood, whereas hardwood has a higher proportion of xylose units. The lignin content of softwood is higher than that of hardwood (7).

In the remaining 5% of weight are numerous other high and low molecular weight organic and inorganic compounds, including proteins, which can be extracted ("wood extractives"). These low molecular compounds include terpenes, terpene derivates such as abietic acid, phenolic compounds, tannins, stilbenes, flavonoids, and glycosides, many with known sensitizing and irritative properties (9). Other chemical compounds that have to used to treat the wood prior to processing such as chromated copper arsenate (CCA) may also be carcinogenic.

Dust generated from wood processing is therefore a heterogeneous mixture of inorganic and organic particles: wood fragments, viable and non-viable microorganisms, endotoxins, glucans, allergens, or mycotoxins, which are all potentially hazardous upon inhalation (6).

Afanou et al. (10) have demonstrated that the composition of fungal spores present in wood dust is heterogeneous and comprises on average 9% submicronic fragments, 62% large fragments and 29% spores. The average concentrations of large and submicronic fragments (0.2–1 µm) were 3×10^5 and 0.6×10^5 particles/m^3, respectively, and correlated weakly with spores (1.4×10^5 particles/m^3).

2.5. EPIDEMIOLOGY OF ALLERGIC SENSITIZATION, RHINITIS AND ASTHMA ASSOCIATED WITH WOOD DUST

The association between exposure to wood dust and asthmatic symptoms has been documented previously (1).

The global prevalence of asthma in woodworkers is between 5.6% to 18%(1, 6, 10, 11). A meta-analysis of wood dust exposure and risk of asthma showed that the pooled relative risk (RR) of asthma among workers exposed to wood dust was 1.53 (95% CI 1.25–1.87). When the analysis was restricted to studies carried out on Caucasian populations, the pooled RR was 1.59 (95% CI 1.26–2.00) while the pooled RR of studies on Asian populations was 1.15 (95% CI 0.92–1.44) (12).

Table 2.2 reports on various epidemiological studies of asthma and other respiratory symptoms. While the prevalence of asthma in wood workers globally, based on various different definitions, is between 6-18%, the prevalence in Africa appears to be lower, between 3-7% (5). The prevalence of rhinitis appears to be much higher ranging between 16-33%. Woods species such as Pine, Mahogany, African teak, Red cedar and Imbuia are associated with a high prevalence of asthma and rhinitis. Fibre- and chipboards and *Mansonia* are also associated with a high prevalence of rhinitis.

Among the three cohort studies presented, Jacobsen et al. (13) in their investigation of the association between cross-shift and longitudinal changes in lung function (FEV_1) among woodworkers in a 6-year follow-up study found no association between acute lung function changes and accelerated lung function decline. Heikkilä et al. (14) study of asthma incidence in wood-processing industries in Finland reported a significantly increased incidence of asthma in both woodworkers and blue-collar workers, but without a clear dose–response relationship. Whilst a Jacobsen et al. (15) investigating the occurrence of new respiratory symptoms in relation to wood dust exposure in a 6-yr follow-up study, demonstrated an increased incidence of coughing and bronchitis among female woodworkers, but no association was shown for male woodworkers.

Table 2.2: Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma (the studies are listed in order of publication date, from most recent to oldest)

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Wood working plants Hosseini et al., 2020, Iran) (16)	Not stated	276	Respiratory symptoms and spirometry changes	Not stated	Symptoms: rhinorrhea 4%, cough 40.2%, phlegm 40.6%, chest tightness 38%, wheezing 25.3%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in this study not stated; no information on working departments; unable to link respiratory symptoms with specific jobs or tasks; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species
Particleboard factories Asgedom el al., 2019,Ethiopia) (3)	Particleboard production	74	Respiratory symptoms	Eucalyptus	Symptoms: cough 39%, cough with sputum production 31%, phlegm27%, wheezing45%, shortness of breath 24%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in this study not stated; lack of power due to small sample size
Wood working plants (Demissie et al., 2019, Ethiopia) (17)	Not stated	70	Respiratory disorders	Not stated	Asthma: 7.9%	-	Asthma: FEV_1 /FVC <70%) and clinically	Cross sectional study design – temporality could not be established; clinical parameters considered for asthma definition not stated; no information on working departments; unable to link respiratory symptoms with specific jobs or tasks; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species; lack of power due to small sample size

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Wood working plants (Demissie et al., 2019, Ethiopia) (18)	Not stated	70	Respiratory symptoms	Not stated	Symptoms: cough41.4%, phlegm 34.3%, breathlessness 21.5%, wheezing 12.4%.	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in this study not stated; no information on working departments; unable to link respiratory symptoms with specific jobs or tasks; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species; lack of power due to small sample size
Furniture plant (Paraskevaidou et al., 2019, Greece) (19)	Wood exposure group (wood processing sector) Chemical exposure group (furniture painting and mounting) Control group (offices)	83	Asthma and rhinitis	Mainly: Particleboard (MDF) and fiberboard Infrequently:pine, beech, and oak	Chemical exposure grp - Asthma: 22.9% Rhinitis: 25.7 Wood exposure grp - Asthma: 8.7% Rhinitis: 17.4% Control grp - Asthma: 4% Rhinitis: 8% Asthma and rhinitis: 4%	-	Asthma: Improvement in FEV_1>12% and >200ml after bronchodilator Rhinitis: increased resistance in rhinomanometry	Cross sectional study design – temporality could not be established and lack of power due to small sample size

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Sawmill plants (Neghab et al., 2018, Iran) (20)	Sawmills	100	Respiratory symptoms and lung function	Not stated	Cough 28% Wheezing 37% Chest tightness 27% Phlegm 24%	12.06(3.47 – 41.93) 4.80 (2.26 – 10.21) 2.52 (1.19 – 5.36) 4.20 (1.57 – 11.25)	-	Cross sectional study design – temporality could not be established; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species; lack of power due to small sample size
Sawmill Factory (Chaiear et al., 2018, Thailand) (21)	Sawmill	279	Respiratory symptoms and lung function	Rubber wood	Upper respiratory symptoms 67%, Lower respiratory symptoms 63.1%, Possible asthma 64.2%, Probable asthma 2.5%	-	Wood dust induced asthma: i) history of wood dust exposure; ii) symptoms after wood dust exposure or a duration of at least two weeks such as cough, dyspnea, wheezing while working and improving after work, and iii) reversible obstructive airway disease by pulmonary function test or a positive methacholine challenge test	Cross sectional study design – temporality could not be established
Wood working plants (Wiggans et al., 2017, UK) (22)	Not stated	269	Respiratory symptoms, lung function and sensitisation	Not stated	Work-related nasal symptoms 13%, work-related ocular symptoms 14%, Asthma (doctor diagnosed 9% and ECRHS 15%) Atopy 20%)	-	Asthma: physician diagnose and ECRHS (wheezing, nocturnal chest tightness, exertional/nocturnal/resting breathlessness, or asthma medication use within the last 12 months	Cross sectional study design – temporality could not be established; no information on working departments; unable to link respiratory symptoms with specific jobs or tasks; types of woods used not stated making it difficult to link health outcomes with specific wood species

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Sawmill plants (Tobin el al. 2016, Nigeria) (23)	Sawmills	227	Respiratory symptoms	Not stated	Cough 46.7%, phlegm 50.2%, wheeze 5.3%, chest tightness 10.1%, chest pain 5.7% and breathlessness 7.5%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in this study not stated; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species.
Carpentries plants (Nde et al., 2015, Cameroon) (24)	Carpentries	135	Respiratory symptoms and pulmonary function	Not stated	Cough 34.5%, expectoration 3.1%, dyspnoea 4.1%, Rhinitis 30%, Airflow obstruction 6.2%, Restrictive disorder 17.5% Mixed syndrome 0.5%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma in this study not stated; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species; lack of power due to small sample size.
Sawmill plant (Mumuni M., 2015, Ghana) (4)	Sawmills	155	Respiratory symptoms	Not stated	Cough 77.4%, wheezing 47.8%, tightness of chest 47.7%, shortness of breath 52.9%, and phlegm production 60.6%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in this study not stated; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Furniture factory (Soongkhang and Laohasiriwong, 2015, Thailand) (25)	Furniture Factory	511	Respiratory symptoms	Not stated	Cough 18.8%, sputum production 15.7%, stuffy nose 15.1%, breathless 7.8%, wheezing 5.1%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma in this study not stated; types of woods used in the production process are not mentioned making it difficult to link
Chip Wood Factory (Abraha N, 2014, Ethiopia) (26)	Production department and technique department	50	Respiratory symptoms and pulmonary function	Particleboard and laminated boards	Cough 58% Phlegm 56% Wheeze 52% Breathlessness 48%	12.42 (4.22 - 36.64) 4.51 (1.89 – 1 0.79) 4.33 (1.78 – 10.53) 4.15 (1.67 – 10.27)	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in this study not stated; lack of power due to small sample size.
Sawmill plant (Adeoye, et al., 2014, Nigeria) (27)	Sawmill	50	Respiratory symptoms and peak expiratory flow	Not stated	Cough 60%, phlegm production 46%, sneezing 54%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in this study not stated; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species; lack of power due to small sample size.
Furniture factories (Jacobsen et al., 2013, Dinamark) (13)	Wood-working, assembly, stock departments	817	Cross-shift changes of FEV_1 at baseline and FEV_1 and at follow-up	Pinewood, particle board hardwood, beech medium-density fiberboard, and mixed	-	–	–	Participation rate in the follow-up study was 63%, which may have caused selection bias (healthy workers selection in the cohort, as individuals who experience respiratory symptoms might be more prone to leave the industry).

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Carpentries plants (Boskabady et al. 2010, Iran) (28)	Carpentries	66	Work-related respiratory symptoms and pulmonary function	Not stated	Work-related respiratory symptoms (53%) Cough 34.4% Sputum 33.3% Wheeze 15.15%	RR (95% CI): 0.22 (0.11-0.45) 0.27 (0.14-0.54) 0.71 (0.36-1.40)	-	Cross sectional study design – temporality could not be established; prevalence of asthma in this study not stated; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species; lack of power due to small sample size.
Sawmill plants (Ugheoke 2009, Nigeria) (29)	Not stated	228	Respiratory symptoms	Mansonia, Iroko and Walnut sp	Symptoms: cough 35.1%, breathlessness 8.3%, wheeze 3.1%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in these studies not stated; no information on working departments; unable to link respiratory symptoms with specific jobs or tasks
Furniture factories Jacobsen et al., 2009, Denmark) (15)	Woodworking, assembly, stock departments	1.377	Respiratory symptoms	Pinewood, particle board hardwood, beech medium-density fiberboard, and mixed	-	Daily coughing (with reference to the lowest exposure quartile) was 1.6 (0.6–4.3), 3.2 (0.9–6.8) and 3.8 (1.5–9.7), respectively, in the second and third lowest and the highest quartile. Chronic bronchitis were, accordingly, 2.3 (0.4–14.5), 3.0 (0.5–18.7) and 6.0 (1.2–28.8). 3.0 (0.5–18.7)	Ever-asthma was defined as current or ever self-reported asthma. Asthma symptoms was defined if the subject answered yes to at least one group A question and two or more group B questions or at least two group A questions	The overall participation rate in the follow-up study was 67%, which may potentially cause skewing of risk estimates due to selection bias.

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Wood-processing industries (Heikkilä et al. 2008, Finland) (14)	Woodworker, other blue-collar workers, and administrative personnel	170.973	Asthma incidence	Spruce, pine, and birch	Asthma	RR (95% CI) Woodworkers: Men: 1.5 (1.2–1.8) Women: 1.5 (1.2–1.7) Other blue-collar workers: Men: 1.5 (1.2–1.8) Women: 1.4 (1.2–1.6)	Asthma: if he or she received rights for reimbursement for asthma medication from the Social Insurance Institution or was registered as having occupational asthma in the Finnish Register on Occupational Diseases	Incidence of asthma was based on information collected from the Social Insurance Institution or the Finnish Register on Occupational Diseases; objective markers for asthma absent.
Furniture industry (Publio 2008, Brazil)(30)	Furniture, painting and finishing	499	Respiratory symptoms	Not stated	Asthma symptoms: 5.6%; Rhinitis: 16%	-	Asthma: symptoms such as wheeze and attack of shortness of breath Rhinitis: nasal congestion, rhinorrhoea and sneezing	Cross sectional study design – temporality could not be established; determination of the prevalence of asthma was based on respiratory symptoms; unable to link respiratory symptoms with specific jobs or tasks; objective markers for asthma absent; types of woods used in the production process are not mentioned making it difficult to link health outcomes with specific wood species
Carpentry, sawmill plant (Aguwa et al. 2007, Nigeria) (31)	Carpentry, sawmill, carving and timber marketing	591	Occupational asthma and rhinitis	Mahogany, Iroko, cedar and Mansonia	Asthma: 6.3% Rhinitis: 78%	-	Asthma: having wheezing and breathlessness, Rhinitis: having one or more of the following: sneezing, rhinorrhoea and/or nasal/pharyngeal itching	Cross sectional study design – temporalitycould not be established; determination of the prevalence of asthma was based on respiratory symptoms; markers for asthma absent

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Sawmill (Fox, 2004, RSA) (32)	Dry mill - stress grading, Wet mill - green chain, stacking and kilns	392	Asthma	Pine	Asthma: Definite 0.5% Probable 2.6% Possible 10.2%	-	Definite: positive questionnaire and 15% improvement in FEV_1 salbutamol or 15% or more improvement after return from leave, Probable: positive questionnaire and >10 to <15% improvement in FEV_1 after salbutamol or on return from leave or, a doctor diagnosis of asthma, Possible: positive questionnaire (except doctor diagnosed asthma)	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in these studies not stated; objective markers for airway inflammation absent
Furniture plant (Arbak et al., 2004, Turkey) (33)	Furniture-decoration	64	Respiratory symptoms and peak expiratory flow rates	Fir tree (*Aberia mulleriana*)	Symptoms: nasal 34.4%, cough 23.4 %, Shortness of breath 18.8 %, Chest tightness 15.6% and Wheezing 14.1%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in these studies not stated; lack of power due to small sample size
Plywood and wood working plant (Borm et al., 2002, Indonesia)(34)	Veneer preparation, Veneer peeling, Veneer drying, Assembly, Grading, Composer and Finishing	982	Respiratory symptoms, lung function, and nasal cellularity	Meranti	Symptoms: cough 23.5 %, shortness of breath 4.1%, wheezing 1.6%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis in these studies not stated

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Furniture factory (Malinowski et al, 2002, Poland)(35)	Sawing, Trimming, sanding, plaining departments and varnishing workshop	48	Work-related symptoms	Fiber- and chipboards	Symptoms: cough 52.1%, shortness of breath 12.5%. Asthma: 6.2% Rhinitis: 33.3%	-	Asthma: specific inhalation challenge test, Rhinitis: rhinorrhea and nasal congestion	Cross sectional study design – temporality could not be established; lack of power due to small sample size; objective markers for airway inflammation absent
Furniture factories (Schlünssen et al., 2002, Denmark)(36)	Sanding, cutting, assembling and packing	2507	Respiratory Symptoms and Lung Function	Pinewood, particle board hardwood, beech medium-density fiberboard, and mixed	Asthma: 6.3% Rhinitis: 19.2%	-	Asthma: subject answered "yes" to at least one group A question (Have you been told by a doctor that you have asthma? Do you have asthma? Have you ever had asthma? Do you ever had wheeze?) *And* two or more group B questions (Do you ever have chest tightness? Do you wake in the night with chest tightness? Do you wake in the night wheezing?). Rhinitis: if the subject answered "yes" to at least two nasal symptoms (rhinorrhea, nasal itching, nasal congestion, or sneezing) at least 2 days a week	Cross sectional study design – temporality could not be established; prevalence of asthma was based on respiratory symptoms without objective criteria; objective markers of airway inflammation absent

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	Department	N	Outcome measure	Woods implicated	Prevalence/ Incidence %	OR (95% CI)	Definition of asthma and Rhinitis	Study limitations
Small-scale wood Industries (Rongo et al., 2002, Tanzania)(8)	Planing, sawing, carving, and drilling	546	Respiratory Symptoms and Dust Exposure	African teak, Mahogany, Bloodwood, East African camphor, East African Afzelia	Asthma 5 -7%	OR=1.9, 95% CI= 1.1-3.4	Asthma: asthmatic symptoms such as shortness of breath with wheezing	Cross sectional study design – temporality could not be established; prevalence of asthma was based on respiratory symptoms without objective criteria; objective markers of airway inflammation absent
Sawmill (Douwes et al., 2001, New Zealand)(37)	Administration, green mill, planer mill, remanufacturing and molding	772	Asthma and Other Respiratory Symptoms	Pine	Symptoms: Wheezing 29.6% Asthma: 18%	OR=1.6 (1.1±2.3) OR=1.4 (1.1±1.9)	Asthma: positive response to either woken by shortness of breath in last 12 months or asthma attack in last 12 months or current asthma medication	Cross sectional study design – temporality could not be established; prevalence of asthma was based on respiratory symptoms without objective criteria; objective markers of airway inflammation absent
Sawmill (Mandryk et al., 2000, Australia)(11)	Three green mills and two dry mills	87	Work-related symptoms	Eucalyptus	Symptoms in dry mill: Asthma in dry mill: 11.8% (cough 29.4%, breathlessness 8.8%, wheezing 8.8%, chest tightness 11.8%) Green mill: asthma 7.5 %, (cough 50.9%, dyspnoea 24.5%, wheezing 24.5%, chest tightness 28.3%)	-	Asthma like symptoms	Cross sectional study design – temporality could not be established; lack of power due to small sample size; prevalence of asthma was based on respiratory symptoms without objective criteria; objective markers for airway inflammation absent

Table 2.2 (continued): Epidemiological studies of wood workers with airway symptoms, rhinitis and asthma

Type of workforce (author, yr. published, Country)	**Department**	**N**	**Outcome measure**	**Woods implicated**	**Prevalence/ Incidence %**	**OR (95% CI)**	**Definition of asthma and Rhinitis**	**Study limitations**
Furniture industry (Talini et al., 1998, Italy)(38)	Furniture manufacturing spray painting and assembling	296	Asthma-like symptoms, atopy and bronchial hyperresponsiveness	Pine and beech	Asthma 7.7%	Atopy and asthma symptoms: OR=19.4; smoking and chronic cough, chronic phlegm, and wheeze: OR=18.3	Asthma: symptoms such as chronic cough, wheeze, attack of shortness of breath, Non-specific bronchial hyperreactivity: when a provocative dose with a fall of 20% in forced expiratory volume in 1 second (PD_{20} FEV_1) was <0.8 mg, Atopy: presence of at least one positive response to skin prick tests	Cross sectional study design – temporality could not be established; objective markers for airway inflammation absent
Wood processing factories (Alwis, 1998, Australia)(7)	Two logging sites, four sawmills, one major wood chipping operation and five joineries	195	Symptoms	Eucalyptus, *Pinus radiata* Meranti (*Shorea spp),* Western red cedar (*Thuja plicata*), Brushbox (*Tristania conferata*)	Symptoms: breathlessness 17.4%, wheezing 22.6% chest tightness 27.2%. Asthma:10.8%	-	-	Cross sectional study design – temporality could not be established; study definition of asthma not clearly stated
Furniture plant (Shamssain, 1992, RSA)(39)	Not stated	145	Pulmonary function and symptoms	Pine and medium density board fibre wood	Symptoms: nasal symptoms 49%, cough 43%, and phlegm 15%	-	-	Cross sectional study design – temporality could not be established; prevalence of asthma and rhinitis not stated; working departments not stated; unable to link respiratory symptoms with specific jobs or tasks

Besides epidemiological studies reported in Table 2.2, many case reports have been reported in literature. Table 2.3 summarizes these studies done in various countries, among workers with different professions and duration of exposure using objective diagnostic criteria implicating various different wood species in the causation of occupational asthma and rhinitis.

Table 2.3: Summary of case reports and case series of wood dust allergy, rhinitis and asthma (publications are listed from the most recent to older)

Author, year, Country	**Department**	**Type of wood implicated**	**No. cases**	**Professions**	**Duration of exposure prior to symptoms**	**Reported health effects**	**Confirmation diagnosis of allergy or asthma**
(Ngajilo et al., 2018, RSA) (40)	-	Obeche wood (*Triplochiton scleroxylon*)	1	Wood sander and stainer	5 years	Asthma, urticaria	Work-related asthma symptoms; PEF with single-day variability of 26%
(Lee & Tan, 2009, *Singapore*) (41)	Carpentry	*Chengal (Neobalanocarpus hemeii)*	1	Carpenter	1 year	Asthma, rhinitis	Decline of PEF, Positive bronchial challenge test
(Algranti et al., 2005, Brazil)(42)	Sawmill	*Ipe (Tabebuia spp)*	1	Sawyer and trimmer	few months	Asthma	Positive bronchial challenge test, improvement of FEV_1 and FEV_1/FVC after removal from exposure
(Jeebhay et al., 1996, RSA)(43)	Sand papering in furniture industry	*Imbuia* (Brazilian walnut)	1	Joinery worker	4 years	Asthma	Positive bronchial challenge test, presence of precipitating IgG in patient's serum
(Spiewak et al., 1994, Poland)(44)	Carpentry	Ash *(Fraxinus excelsior),* Oak *(Quercus sp.),* Beech *(Fagus silvatica) and* Pine *(Pinus sylvestris)*	1	Carpenter	15 years	Asthma, rhinitis	Positive bronchial challenge test
(Cartier et al., 1986, Canada)(45)	Sawmill	Eastern white cedar *(Thuja occidentalis)*	1	Sawmill worker	after a few weeks	Asthma	Change in PEF and bronchial responsiveness to histamine and inhalation challenge test, late decline in FEV_1, specific IgE

Table 2.3 (continued): Summary of case reports and case series of wood dust allergy, rhinitis and asthma

Author, year, Country	Department	Type of wood implicated	No. cases	Professions	Duration of exposure prior to symptoms	Reported health effects	Confirmation diagnosis of allergy or asthma
Hinojosa et al. 1984, Spain)(46)	Carpentry	African maple *(Triplochiton scleroxylon)*	2	Carpenter	2 months	Dyspnoea, wheezing, sneezing, rhinitis	Immediate decline in FEV_1 for bronchial provocation test. Positive skin prick test and specific IgE
(Bush & Clayton 1983, *USA*)(47)	Furniture	Central American Walnut *(Juglans olanchana)*	1	Woodworker	not stated	Rhinorrhea, cough, wheezing, dyspnea	Decline in FEV_1, negative skin prick test and RAST
*(*Paggiaro et al. 1981, *Italy*)(48)	-	*Tanganyike anigré*	3	Woodworker	Days to 3 months	Asthma, dyspnoea, cough, wheezing, itchiness, rhinorrhea	Positive skin prick test and decline in FEV_1 in two subjects, negative precipitin test or specific IgE
(Raghuprasad et al 1980, USA)(49)	-	Quillaja bark (soap bark) (*Quillaja saponaria*)	1	Spray drier operator	3 months	Asthma, rhinitis, lacrimation, itchiness of eye, sneezing, dyspnoea, wheezing	Immediate bronchoconstriction, faintness, diffuse erythema, hypotension
(Bush et al., 1978, USA)(50)	-	African Zebra wood (*Microberlinia* species)	1	Woodworker	5 months	Asthma, cough, dyspnea	Positive skin prick test, dual decline in FEV_1 for bronchial challenge test, a positive RAST
(Booth et al., 1976, USA)(51)	-	Abiruana (*Lucuma* species)	2	Furniture makers	Days to 1 year	Asthma, nocturnal dyspnoea and cough	Decline in FEV_1, FVC, MMF when provoked, positive skin test, positive precipitin test
(Chan-Yeung and Abboud 1976, Canada)(52)	-	California redwood (*Sequoia sempervirens*)	2	Carpenters	2 -3years	Asthma, dyspnoea, wheezing	Immediate, delayed and dual decline in FEV_1

Table 2.3 (continued): Summary of case reports and case series of wood dust allergy, rhinitis and asthma

Author, year, Country	Department	Type of wood implicated	No. cases	Professions	Duration of exposure prior to symptoms	Reported health effects	Confirmation diagnosis of allergy or asthma
(Howie et al., 1976, Scotland)(53)	-	Ramin (*Gonystylus bancanus*)	1	Woodworker	4 – 6 hours	Asthma, dyspnoea, cough, shivering sweating, tiredness	Decline in FEV_1, positive serum antibodies, negative skin patch test
(Eaton, 1973, UK)(54)	-	Cocabolla (*Dalbergia retusa*)	3	Furniture makers	Day to 18 months	Chest tightness, wheeze, dry cough, nasal obstruction, frontal headache dermatitis	Positive skin prick test
(Pickering et al., 1972, UK)(55)	-	Western red cedar (*Thuja plicata*); Iroko (*Chlorophora excelsa*)	1 1	Carpenter Carpenter	1 year Unknown	Asthma with dyspnea	Positive skin prick test and a positive serum antibodies for Iroko only and a decline in FEV_1 for both woods
(Gandevia & Milne 1970, Australia)(56)	Joiner's shops	Western red cedar (*Thuja plicata*)	6	Joiners	1 month to 6 years	Asthma and rhinitis, nocturnal cough, sneezing, dyspnoea, wheezing, persistence symptoms after cessation of exposure	Confirmed by decline in FEV_1 to bronchial provocation test, mild or absent skin test, negative precipitin test
(Sosman et al., 1969, UK)(57)	-	Oak Mahogany Cedar	1 1 2	Mill worker Pattern maker Carpenter	12 years 16 years 18 years	Asthma, cough, rhinitis and dyspnea	Positive serum antibodies

2.6. EXPOSURE AND CAUSATIVE AGENTS

Furniture workers are exposed to several sensitizers and irritants including wood dust per se, “wood extracts” (terpenes, terpene derivatives such as abietic acid, plicatic acid), endotoxins, glucans, isocyanate vapours and other chemicals (including glues, dyes, varnishes, paints, solvents, hardeners) (17, 20).

Table 2.4 presents the exposure concentrations of different components present in wood dust reported in various studies. These studies have demonstrated that workers in the wood processing industry are exposed to variable concentrations of hazardous agents (microorganisms, endotoxins, glucans and terpenes) associated with wood dust. The exposure estimates have wide ranges viz. wood dust particulate (0.05 and 12.0 mg/m^3, microorganisms (1.696 and 2000 cfu/m^3 x10^3), endotoxins (0.4 and 6.93 ng/m^3), glucans (3.5 and 18.9 ng/m^3) and terpenes (0.23 and 158 mg m^3). As expected, dry mills had higher particulate dust levels than wet mills.

Teschke et al. (58) initially suggested that weather conditions, tree species, wood condition, jobs, tasks, type of equipment used and certain control measures were among the potential determinants of exposure to inhalable particulate, wood dust, resin acids, and monoterpenes in a lumber mill environment. Furthermore, Ronald et al. (59)found that weather conditions, log storage methods (land-storage or water-storage), wood condition (dry or green), tree species, production level, jobs and tasks were among the potential determinants of exposure to β (1-3)-glucans in sawmills. In studying the determinants of wood dust exposure in the Danish furniture industry Schlünssen et al.(60) reported that sanding of wood, use of fully-automatic machines, manual work, cleaning of work pieces with compressed air, kitchen producing factories and small factories (<20 employees) were associated with increased wood dust concentrations. On the other hand, manual assembling or packing, sanding with adequate exhaust ventilation, vacuum cleaning of machines and employment of special cleaning staff decreased dust concentrations. The New Zealand study by Douwes’ et al.(61) demonstrated that the use of hand tools and conventional cleaning methods (dry wiping and sweeping) significantly contributed to high exposures in in joineries and furniture manufacturingwhilst the use of vacuum extraction on hand tools and alternative cleaning methods were significantly associated with reduced wood dust exposures.

Table 2.4: Summary of exposure assessment studies conducted in wood processing workplaces (publications are listed from the most recent to older)

Ref.	Country	Types of wood	Dust fraction	N	Job title	Wood dust conc. (mg/m^3)	Micro-organisms conc. (cfu/m^3 $x10^3$)	Endotoxin conc. (ng/m^3)	Glucans conc. (ng/m^3)	Fungal particle conc. ($particle/m^3$)	Resin acid conc. (ng/m^3)	Terpene conc. ($\mu g/m^3$)
(Asgedom et al. 2020)(62)	Ethiopia	Eucalyptus trees	Inhalable	152	Particle-board factories workers	GM 4.66	-	62.2 EU	-	-	-	-
(Afanou et al. 2018)(10)	Norway	Spruce (*Picea abies*)	Thoracic particles	31	Sawmill	-	-	-	-	Spores: 1.4 x 10^5 Large fragments: 3 x 10^5 Submicronic fragments: 0.6 x 10^5	-	-
Straumfors et al., 2018)(2)	Norway	Spruce (Picea abies) and Pine (Pinus sylvetris)	Thoracic and inhalable	205	Sawmill	Thoracic: 0.09 Inhalable: 0.72	-	Thoracic: 3.0 EU Inhalable: 17 EU	-	Thoracic: 2 x 10^5 fungal fragments/m^3 Inhalable: 0.4 x 10^5 fungal spores/m^3	Thoracic: 1,560 Inhalable: 7,508	Monoterpene: 1,105 Sesquiterpene: 40

GM – Geometric mean; GSD - Geometric standard deviation

Table 2.4 (continued): Summary of exposure assessment studies conducted in wood processing workplaces

Ref.	Country	Types of wood	Dust fraction	N	Job title	Wood dust conc. (mg/m^3)	Micro-organisms conc. (cfu/m^3 $x10^3$)	Endotoxin conc. (ng/m^3)	Glucans conc. (ng/m^3)	Fungal particle conc. ($particle/m^3$)	Resin acid conc. (ng/m^3)	Terpene conc. ($\mu g/m^3$)
(Aalew et al. 2015)(63)	Ethiopia	Medium-density Fiberboard, Austrian Pine, Plywood, *Cordia africana, Olea europea-cuspidata, and Pouteria adolfi-fredericii*	Inhalable	360	Wood-workers	6.82	-	-	-	-	-	-
(Jacobsen et al. 2013)(13)	Denmark	Not stated	Inhalable	817	Wood-workers	0.2–9.8	-	-	-	-	-	-
(Klarić et al. 2012)(64)	Croatia	Sawmill 1: beech, oak and fir wood Sawmill 2: ash, beech and oak	-	96	-	-	1,696-7,316 in Sawmill 1 and 1,706-4,819 in Sawmill 2	-	-	-	-	-
(Gioffrè et al. 2012)(6)	Italy	Not stated	Inhalable	24	Sawmill Carpenters	0.05 -12.0	130 – 2000	0.40 -6.93 (2 - 35 EU)	-	-	-	-

GM – Geometric mean; GSD - Geometric standard deviation

Table 2.4 (continued): Summary of exposure assessment studies conducted in wood processing workplaces

Ref.	Country	Types of wood	Dust fraction	N	Job title	Wood dust conc. (mg/m^3)	Micro-organisms conc. (cfu/m^3 x10^3)	Endotoxin conc. (ng/m^3)	Glucans conc. (ng/m^3)	Fungal particle conc. (particle/ m^3)	Resin acid conc. (ng/m^3)	Terpene conc. (µg/m^3)
(Hagström et al 2012)(65)	Denmark	Pine	Inhalable	161	Furniture workers	GM 0.58	-	-	-	-	-	12.0
(Osman & Pala, 2009)(66)	Turkey	Medium-density fiberboard, beech and fiberboard	Inhalable	328	Furniture workers	2.04±1.53	-	-	-	-	-	-
(Hagström et al. 2008)(67)	Sweden	Compressed pine	Inhalable	44	Wood pellet production workers	0.6 – 12	-	-	-	-	-	0.23 – 25
(Spee et al. 2007)(68)	Netherland	Not stated	Inhalable	26	Carpenter s	GM: 3.3 GSD 2.1	-	-	-	-	-	-
(Douwes et al. 2006)(69)	New Zealand	Pine (*Pinus radiate*)	Inhalable	226	Sawmill workers	GM: 0.52±2.66	-	-	-	-	-	-
(Rongo el al. 2004)(70)	Tanzania	Teak, mahogany, camphour, mtanga (albizia ssp), cedar, podo, pine, and cypress.	inhalable	281	Wood-workers	3.30	-	91 EU/m^3	-	-	-	-

GM – Geometric mean; GSD - Geometric standard deviation

Table 2.4 (continued): Summary of exposure assessment studies conducted in wood processing workplaces

Ref.	Country	Types of wood	Dust fraction	N	Job title	Wood dust conc. (mg/m^3)	Micro-organisms conc. (cfu/m^3 x10^3)	Endotoxin conc. (ng/m^3)	Glucans conc. (ng/m^3)	Fungal particle conc. (particle/m^3)	Resin acid conc. (ng/m^3)	Terpene conc. (µg/m^3)
(Fox 2004)(32)	RSA	Pine	Total	392	Sawmill workers	GM: Dry mill 5.11 ; GM: Wet mill 0.7	-	-	-	-	-	-
(Ronald et al. 2003)(59)	Canada	Engelmann Spruce (*Piceaengelmannii*)/ White Spruce (*Picea glauca*), Lodgepole Pine (*Pinus contorta*), and Balsam Fir (*Abies lasiocarpa*), Western Hemlock (*Tsugaheterophylla*) and Douglas Fir (*Pseudotsuga menziesii*)	Inhalable	275	Sawmill workers	-	-	-	3.5 - 18.9	-	-	-
(Krysinska et al. 2002)(71)	Poland	Furniture 1: beech Furniture2: fiberboards and chipboards	Total	-	-	-	10.7 ± 9.9 3.6 ± 2.5	-	-	-	-	-

GM – Geometric mean; GSD - Geometric standard deviation

Table 2.4 (continued): Summary of exposure assessment studies conducted in wood processing workplaces

Ref.	Country	Types of wood	Dust fraction	N	Job title	Wood dust conc. (mg/m^3)	Micro-organisms conc. (cfu/m^3 x10^3)	Endotoxin conc. (ng/m^3)	Glucans conc. (ng/m^3)	Fungal particle conc. (particle/m^3)	Resin acid conc. (ng/m^3)	Terpene conc. (µg/m^3)
(Rongo et al. 2002)(8)	Tanzania	East African teak (Chlorophora excelsa), mahogany (Khaya nyasica), blood wood (Pterocarpus angolensis), East African camphor (Ocotea usambarensis), East African Afzelia Burl (Afzelia quanzensis), “mtanga” (Albizia ssp), African pencil cedar (Juniperus procera), African blackwood (Dulbergia melanoxylon), “kawilia” (Grevillea robusta). Podo (Podocarpus gracilion), cypress (Taxodium distichium), and pine (Pinus patulla)	Inhalable	106	Wood-workers	GM: 3.86	-	-	-	-	-	-

GM – Geometric mean; GSD - Geometric standard deviation

Table 2.4 (continued): Summary of exposure assessment studies conducted in wood processing workplaces

Ref.	Country	Types of wood	Dust fraction	N	Job title	Wood dust conc. (mg/m^3)	Micro-organisms conc. (cfu/m^3 x10^3)	Endotoxin conc. (ng/m^3)	Glucans conc. (ng/m^3)	Fungal particle conc. (particle/m^3)	Resin acid conc. (ng/m^3)	Terpene conc. (µg/m^3)
(Dutkiewicz et al. 2001)(72)	Poland	Pine (*Pinus sylvestris*), fir (*Abies alba*) Oak (*Quercus robur*) and birch (*Quercus robur*)	Inhalable	30	Sawmill workers	-	20.2 ± 5.6 9.8 ± 3.0	0.24- 4.00 (1.2 – 20 EU) -	-	-	-	-
(Mandryk et al. 2000)(11)	Australia	Eucalyptus	Inhalable	93	Sawmill workers	GM: Dry mill 1.71 ; GM :Green mill 1.52	-	Green mill 6.61 (33 EU); Dry mill 1.58 (7.9 EU)	Green mill 3.89; Dry mill 1.91	-	-	-
(Eriksson et al. 1996)(73)	Sweden	Pine	-	48	Sawmill workers	-	-	-	-	-	-	11 – 158

GM – Geometric mean; GSD - Geometric standard deviation

2.7. ADVERSE RESPIRATORY HEALTH OUTCOMES AND PATHOPHYSIOLOGICAL MECHANISMS ASSOCIATED WITH EXPOSURE TO WOOD DUST

Exposure to wood dust and other causative agents associated with wood dust has long been associated with a variety of adverse health effects of the upper and lower airways. Health effects associated with exposure to wood dust and associated agents present in the upper airways include rhinitis and sinonasal carcinoma; while in the lower airways these result in allergic alveolitis, occupational asthma and general lung function deficits (74). It is estimated that about 15% of asthma or COPD is attributable to occupational exposures (75).

The mechanisms for wood dust causing asthma and rhinitis are far from being fully understood (76). For red cedar, a unique constituent, plicatic acid, has been shown to be a causal factor, and both immunological and non-immunological mechanisms are involved (Figure 2.6). For other types of wood no clear causal agent has consistently been found. Specific IgE sensitization has been reported to be responsible for asthma in woodworkers (77), but Type 1 allergy is not suspected to be a major cause of wood dust induced asthma. Formaldehyde-based stabilizers used in wood composite manufacture have also been implicated as respiratory sensitizers. Some authors have identified allergic disease processes for specific woods. However, a single unifying immunological mechanism has yet to be described (78). Apart from IgE mediated sensitization several other mechanisms, including irritative mechanisms have been reported (54).

Kespohl et al., have demonstrated that exposure to wood dust can induce irritative as well as allergic respiratory disease and that the prevalence of sensitization is much higher for tropical woods (30%) compared to non-tropical wood species (3%) (79). In their investigation of the association between high- and low-molecular- weight sensitizing agents in patients with different clinical phenotypes of occupational asthma (OA), Vandenplas et al found that workers exposed to low molecular weight agents such as wood dust were more likely to present with chest tightness at work, daily sputum and late asthmatic reactions as opposed to those exposed to high molecular weight agents, that were more likely to have work-related rhinitis, conjunctivitis, atopy and early asthmatic reactions (80).

Schlünssen et al. (9) concluded that while specific sensitization to wood dust exists, it is probably of minor clinical importance for most wood species and together with the absence of standardised commercial extracts direct comparisons between studies proves to be difficult since most studies use in-house preparations of extracts for SPT and for detection of sIgE.

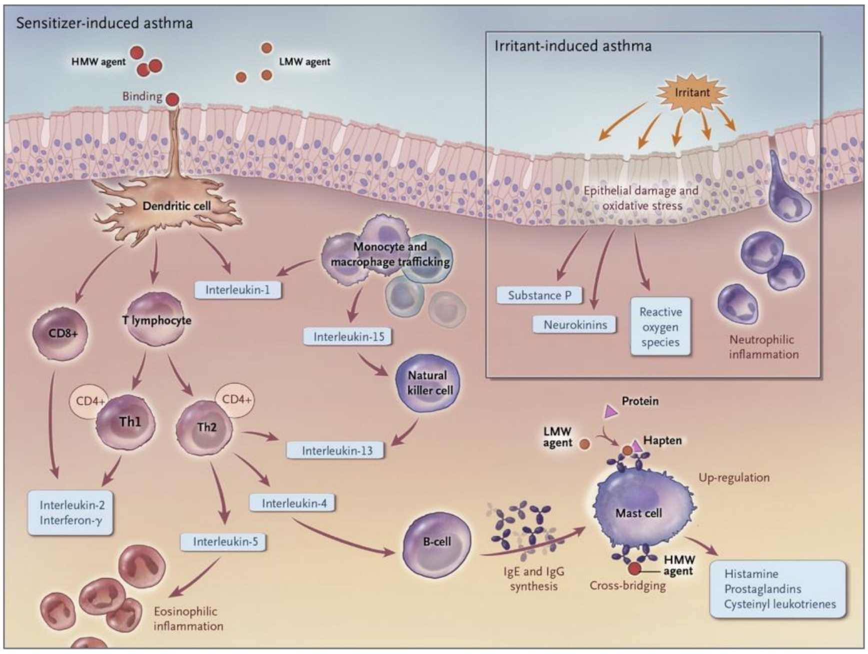


Figure 2.6: Mechanisms involved in sensitizer-induced asthma and irritant-induced asthma (Source: Tarlo and Lemiere) (81)

Animal studies have shown that wood components, such as the major constituent in pine resin, abietic acid, cause direct toxicity via lytic damage to alveolar, tracheal and bronchial epithelial cells. Wood dust extracts from both hard and soft wood are able to induce the release of pro-inflammatory mediators from macrophages, express and induce the release of inflammatory mediators in human epithelial cell line, and modulate the expression of cytokines and chemokines (76).

The oxidative products of monoterpenes or abietic acid can cause airway inflammation through immune reactions. This was supported in an experimental study, which showed increased alveolar cell concentration, mainly macrophages in bronchoalveolar lavage (BAL) after exposure to concentrations of 450 ng/m^3 (76). Pylkkänen et al. (82) studied the capacity of wood dust to induce the production of reactive oxygen species and caspase-3 activity in human bronchial epithelial cells. Dust from three wood species: pine, birch and oak, induced reactive oxygen species (ROS) production and evoked apoptosis (caspase-3 activity) in cultured human bronchial epithelial cells (BEAS-2B), a widely used airway epithelial cell model. Epithelial cells lining the airways form an important physical barrier, and are the primary targets for inhaled particles. Exposure to external particles may induce cellular apoptosis and necrosis of epithelial cells which again may lead to shedding of the bronchial mucosa, to bronchial hyperreactivity, and exacerbation of asthma.

2.8. RISK FACTORS FOR RHINITIS AND ASTHMA IN WOOD WORKERS AND EFFECT MODIFIERS (INCLUDING DOSE-RESPONSE RELATIONSHIPS)

There are various environmental and host risk factors associated with adverse respiratory health outcomes among workers exposed to wood dust.

2.8.1 ENVIRONMENTAL FACTORS

a) Job duration

Aguwa et al (31) in a study of the prevalence of occupational asthma and rhinitis among woodworkers in South-Eastern Nigeria found that the prevalence of occupational rhinitis and asthma among wood workers increases with exposure duration. Among workers with less than 2 years of exposure, the prevalence of rhinitis was 8.7% and of asthma was 1.9%, whereas in workers with more than 10 years of exposure the prevalence of the rhinitis was 36.5% and that of asthma 6.5%.

Meo's study (74) on the effects of wood dust exposure duration on peak expiratory flow among workers in small scale wood industries found that the peak expiratory flow (PEF) in wood exposed workers was negatively associated with years of exposure. In workers with less than 4 years of exposure PEF was 312.28 ± 23.62 liters/min compared to those with more than 8 years was that were found to have a PEF of 177.00 ± 22.29 liters/min.

Shamissain's (39) study of pulmonary function and symptoms in workers exposed to wood dust found that the prevalence of respiratory symptoms increases with the increase in the number of years of employment. Cough and nasal symptoms showed a pronounced increase with years of employment. The prevalence of cough in workers with 1-4 years of employment was 35% while in workers with 9-12 years this was 66%. The prevalence of nasal symptoms in workers with 1-4 years of employment was 49% compared to workers with 9-12 years employment was 55%. The study also found that the proportion of subjects with an FEV_1/FVC ratio below 70% in the exposed group employed for 10-19 years was 56% compared to the 27% in the exposed group with less than 10 years of employment.

The study by Mununi (4) on the respiratory health problems among sawmill workers in the timber market in Accra (Ghana) found that workers who worked for more than 10 years were more likely to develop cough (OR= 1.95; 95% CI: 1.28 – 2.98), produce phlegm (OR= 1.77:

95% CI: 1.16 – 2.69), shortness of breath (OR= 1.31; 95% CI: 0.91 – 1.90) and to experience wheeze (OR= 1.07; 95% CI: 0.75 - 1.53).

b) Exposure concentration

Schlünssen et al (1) found that symptomatic bronchial hyperresponsiveness was related to dust in a dose dependent manner, with OR= 18.3 (95% CI: 2.0–170.8) when comparing the group with the highest (4.10 mg/m^3) to the lowest (0.17 mg/m^3) exposure level. The same tendency was seen for work related asthma symptoms (OR= 6.4; 95% CI: 1.6–26.4).

Schlünssen et al (36) showed in their study of Danish woodworkers, that the prevalence of asthma and rhinitis increases with increasing of level of exposure. The prevalence of asthma in male workers exposed to wood dust levels ranging between 0-0.74 mg/m^3 was 3.9% compared to workers exposed to dust ranging between 0.74-1.42mg/m^3 which was 7.8%. Similarly, the prevalence of rhinitis in workers exposed to wood dust ranging between 0-0.74 mg/m^3 was 19.1% compared to workers exposed to wood dust ranging between 0.74-1.42 mg/m^3, which was 22.3%.

Mandryk et al (11) demonstrated a relationship between exposure to endotoxins and glucans and work-related symptoms in workers of three green mills and two dry mills. The geometric mean (GM) personal inhalable endotoxins (6.61 ng/m^3) and inhalable glucans (2.63 ng/m^3) exposures were high for the green mills compared with those of dry mills 1.58 ±1.52 ng/m^3 (geometric mean ± geometric S.D) and 0.38 ± 1.73 (0.17 ng/m^3) respectively. Green mill workers showed a strong association between personal exposure and work-related symptoms. Significant relationships were found between glucans exposure and nasal congestion (OR = 62; 95% CI: 30.79 - 124.85), endotoxins and nasal congestion (OR = 49; 95% CI: 24.29 - 98.67), when the same logistic model was adjusted for endotoxins and glucans, respectively. Similarly, glucans exposure was associated with chronic bronchitis (OR = 163; 95% CI: 71.52 - 368.71) as was endotoxins (OR = 17; 95% CI: 7.92 - 36.23).

In a study of respiratory symptoms and dust exposure among male workers in small-scale wood industries in Tanzania, allergic symptoms were reported more commonly in the low exposure group with OR= 2.4 (95% CI=1.8 –3.1) and OR= 2.7 (95% CI= 1.8–4.0) for high-exposure groups compared to controls (8).

A study of asthma in New Zealand Pine processing sawmill workers showed that working in pine sawmilling was associated with an increased prevalence of asthma and cough symptoms. Asthma symptoms in the exposed workers (18%) was more common than in the general population (12.1%) with adjusted OR= 1.6 (95% CI= 1.1 – 2.3). Asthma was also more common in the low exposure group (15.6%) and high exposure groups (high exposure to `green dust'; 20.4% and high exposure to `dry dust'; 18.8%) than in non-exposed workers (9.2%). The respective adjusted odds ratios were OR=1.9 (95% CI= 0.7 - 4.9), 2.7 (95% CI= 0.9 -7.6), and 2.1 (95% CI= 0.8 -5.7), but these were not significant. Adjusted odds ratios for symptoms of cough were OR=2.7 (95% CI= 1.2 - 6.5) for the low, OR=5.2 (95% CI 2.1 -13.0) for the high `green dust' and OR=3.3 (95% CI=1.4 -7.9) for the high `dry dust' exposure groups compared to the non-exposed group (37).

An investigation into the increased incidence of respiratory symptoms among female woodworkers exposed to dry wood found the cumulative incidence proportion of daily coughing and chronic bronchitis was associated with baseline wood dust exposure in a dose-dependent manner. The odds ratios for daily coughing (with reference to the lowest exposure quartile) was OR=1.6 (95% CI= 0.6–4.3), OR=3.2 (95% CI= 0.9–6.8) and OR=3.8 (95% CI= 1.5–9.7), respectively, in the second and third lowest and the highest quartile. The figures for chronic bronchitis were, accordingly, OR=2.3 (95% CI= 0.4–14.5), OR=3.0 (95% CI= 0.5–18.7) and OR=6.0 (95% CI= 1.2–28.8) (15).

Lytras et al., in the ECRHS study of occupational exposures and 20-year incidence of COPD also demonstrated that the incidence of COPD increases with increasing of level of exposure (83). The incidence of COPD in workers exposed to biological dust was 3.4% in low exposure group compared to 5.7% in the highly-exposed group, demonstrating a relative risk (95% CI) in the low exposure group of RR=1.5 (1.0 to 2.2) and RR=2.2 (1.2 to 4.0) in the highly exposed.

In exploring dose-response relationships it is important to not only use the concentration of airborne wood dust but also the level of wood dust allergens as an exposure index since allergen concentrations may vary depending on the wood dust or origin. A study of obeche wood allergen quantification assay for the assessment of allergen exposure in workplaces found that obeche wood from Cameroon (called ayous) had less allergen content compared to obeche wood from Ghana (called wawa)(84). Further analysis showed that the reduced allergen content in ayous wood could be ascribed to a reduced amount of major obeche wood allergen Trip s 1. This emphasizes the importance of using the content of wood dust allergens, and not only the concentration of airborne wood dust, in estimating dose-response relations (9).

2.8.2 HOST FACTORS

There are various host-related factors that may either predispose or modify the risks of developing work-related asthma in exposed individuals. These are discussed further below.

a) Genetics

A meta-analysis of wood dust exposure and risk of asthma conducted by Perez-Rios (12) demonstrated a higher risk of asthma in European and American studies than among Asian studies indicating possible genetic factors in the development of asthma. This suggests the existence of interactions between genetic susceptibility to asthma and environmental factors. Several genetic factors are probably responsible for allergen sensitization, which is determined by HLA genotype, including sensitization to occupational agents (85).

Recent GWAS (genome-wide association studies) have convincingly detected a large number of loci associated with allergic diseases. Candidate genes in the susceptibility loci suggest roles for epithelial barrier functions, innate-adaptive immunity, IL-1 family signaling, regulatory T cells and the vitamin D pathway in the pathogenesis of allergic diseases (86), (87). However, specific associations with wood dust exposure have not been documented.

b) Atopy

Schlünssen at al. (1) in the Danish study of asthma among woodworkers demonstrated that atopy was an important modifier of the association between asthma and wood dust exposure. This study demonstrated a stronger association for symptomatic bronchial hyperresponsiveness among atopics (OR= 22.9; CI= 1.0-523.6) exposed to the highest compared to the lowest dust level. Whilst, for work related asthma symptoms the association with dust level was only seen for non-atopics. In woodworkers, asthma was associated with atopy, with elevated odds ratios for symptomatic bronchial hyperresponsiveness (OR=7.4; 95% CI=2.8–19.7) and for asthma symptoms (OR=4.2; 95% CI=2.4–7.7).

Talini (38) found that, in furniture workers, differences in the prevalence of respiratory symptoms among the different job titles was present among atopic subjects, that showed a higher prevalence of chronic cough, wheeze, shortness of breath with wheeze, dyspnoea, and asthma in spray painters (who spray-painted furniture in finishing rooms) when compared to the other groups. In non-atopic subjects, no significant difference between groups was found.

Finally, Chaiear et al. (21) studying respiratory symptoms and pulmonary function among workers in a rubber wood sawmill factory in Thailand found that being atopic (OR = 3.63; 95% CI= 1.88-7.0) was significantly associated with the upper respiratory symptoms.

c) Upper airway symptoms and rhinitis

Occupational rhino-conjunctivitis often precedes the onset of IgE-mediated occupational asthma and it should be considered an important risk factor for future development of occupational asthma (88).

The majority of patients diagnosed with occupational asthma also suffer from occupational rhinitis, which most often precedes the development of occupational asthma, especially when high molecular weight agents are involved. Occupational rhinitis is associated with an increased risk of asthma, although the proportion of subjects with occupational rhinitis who will develop occupational asthma remains uncertain (89).

d) Smoking

The relationship between smoking and occupational asthma is complex and contradictory. However, various studies have shown that smokers are at increased risk of developing sensitization although not necessarily asthma, due to high molecular weight agents and to certain low molecular weight agents that cause asthma through an IgE-mediated mechanism (90). Schlünssen (1) in their study on indices of asthma among atopic and non-atopic woodworkers found that smokers were more often asthmatic, with OR=3.6 (95% CI= 1.7–7.6) for work-related asthma symptoms and OR=2.3 (95% CI=1.0–5.4) for symptomatic bronchial hyperresponsiveness compared to non-smokers.

Ugheoke et al (91) studying the influence of smoking on respiratory symptoms and lung function indices in sawmill workers in Nigeria, demonstrated that smoking sawmill workers were at increased risk of developing respiratory problems compared to control workers.

Tobin et al. (23) studying occupational exposure to wood dust and respiratory health status of sawmill workers in South-South Nigeria found that there was a significantly higher prevalence of all symptoms among current and ex-smokers than among non-smokers.

e) Gender

In a study by Bolund et al (92) of new-onset COPD and decline in lung function among wood dust-exposed workers, an exposure–response relationship was observed only for female smokers (OR=8.47, 95% CI =0.9–82.4) in the highest exposed group compared to controls, with a significant exposure trend. Female woodworkers also had a significantly larger decline in FEV_1 than female controls. None of these changes were observed in men.

Chaiear et al. (21) studying workers in a rubber wood sawmill factory in Thailand found that being female had a two-fold (OR = 2.03; 95% CI= 1.10 – 3.78) increased odds of developing upper respiratory symptoms.

According to the recently published study by Moscato et al. (93) on gender and occupational allergy, the involvement of sex hormones in immune reactions may partly explain different prevalence and clinical manifestations between women and men. However, an increased preponderance of some occupational allergic reactions in women probably reflect differences in sociocultural roles and allergen exposures related to gendered distribution of work, rather than the influence of sex hormones.

2.9. DETERMINANTS OF EXPOSURE TO WOOD DUST, ENDOTOXINS AND β-GLUCANS

In studying the determinants of exposures in wood workers, Teschke et al. (58) initially suggested that weather conditions, tree species, wood condition, jobs, tasks, use of certain types of equipment control measures were among the potential determinants of exposure to inhalable particulate, wood dust, resin acids, and monoterpenes in a lumber mill environment. Furthermore, Ronald et al. (59) found that weather conditions, log storage methods (land-storage or water-storage), wood condition (dry or green), tree species, production level, jobs and tasks were potential determinants of exposure to β (1-3)- glucans in sawmills.

Alwis et al. (94) demonstrated that ageing equipment, poor maintenance of ventilation systems and no segregation of dusty processes were associated with increasing dust level in the wood processing industry. In studying the determinants of wood dust exposure in the Danish furniture Industry, Mikkelsen (95) found that manual and automatic sanding and use of compressed air with fully automatic and semi-automatic machines and for cleaning of work pieces increased dust concentrations. On the other hand, work on the evening shift, supplementary fresh air intake and work in a chair factory was associated with decreased wood dust exposures.

In the Danish furniture industry Schlünssen et al. (60) reported that sanding of wood, use of fully-automatic machines, manual work, cleaning of work pieces with compressed air, kitchen producing factories and small factories (<20 employees) were all associated with increased wood dust concentrations. On the other hand, manual assembling or packing, sanding with adequate exhaust ventilation, vacuum cleaning of machines and the use of special cleaning staff were associated with decreased dust levels. Furthermore, Douwes et al. (96) demonstrated that the use of hand tools and conventional cleaning methods (dry wiping and sweeping) significantly contributed to high exposures in joineries and furniture manufacturing in New Zealand whilst the use of vacuum extraction on hand tools and alternative cleaning methods were associated with significantly reduced wood dust exposures.

2.10. PREVENTION STRATEGIES FOR EXPOSURE TO WOOD DUST AND WORK-RELATED ASTHMA IN WOODWORKERS

Primary prevention of occupational asthma includes reducing exposure in order to prevent development of respiratory disease in susceptible workers.

Control of exposure can be achieved by different control measures and the hierarchical strategy commonly applied is: elimination, reduction, isolation, ventilation, exposure avoidance personal protection (97). The preferred measure is substitution of an agent in the work process, for instance, substitution of woods with strong sensitizing potential with less strong sensitizing woods. When substitution is not possible, exposure reduction, which in practice is achieved through a combination of different interventions is the next best approach. It is important to define a desirable exposure reduction, and exposure standards can play an important role in this process.

a) Exposure standards

Several organizations and countries have set standards or given recommendations for wood dust exposures, which range from 0.5-5 mg/m^3 (Table 2.5), to prevent the development of adverse respiratory health effects. The occupational exposure limits (OELs) vary between countries and professional organisations that have proposed such limits. While professional organisations such as the ACGIH increasingly used health based limits, countries generally base their limits on access to technology and socio-economic considerations (98). This probably explains the discrepancies between the OEL’s for similar types of wood across different countries.

Table 2.5: Recommended occupational exposure limits for wood dust

OEL (mg/m³)				
Country/Agency	**Trees species**	**TWA**	**STEL**	**Notations**
ACGIH (99)	Western Red Cedar All other species	0.5 1	- -	Sensitizer Oak and beech A1 carcinogen
Australia (100)	Hardwoods Softwoods	1 5	- 10	Sensitizer, standard under review
Sweden (101)	All species	2	-	-
Norway (2)	All species	2	-	-
European Union (102)	All species	1-1.5	-	-
The Netherlands (103)	All species	0.2	-	For hardwoods: technical and socioeconomic based OEL = 2 mg/m^3 and health-based OEL is 0.2mg/m^3
New Zealand (104)	Hardwoods Softwoods	1 2	-	-
South Africa (105)	All species	5	-	-

Furthermore, there are currently no international exposure standards for other agents associated with wood dust exposures such as the endotoxins, glucans, fungal spores and fragments and terpenes. However, several recommendations have been formulated or proposed to facilitate the interpretation of data. For endotoxins this ranges between 90-125 EU/m^3. Exposure standards for β-glucans are still a “grey area” (Table 2.6). There are neither exposure standards nor proposals of threshold limit values for this biological agent (106). Rylander showed that the airborne level of β-glucans in indoor environments within the range of 0.1–5.2 ng/m^3 may determine increased frequency of adverse health effect occurrences in the exposed population (Table 2.7) (107). Occupational exposure limits for fungal spores and fragments have been suggested as 10^5 spores/m^3 (108).

While most countries do not have specific exposure limits for monoterpenes, the United States and the Nordic countries (Sweden, Denmark, Norway and Finland) do have specific occupational exposure limits (OELs), which range between 25-100ppm (Table 2.9) (109).

Table 2.6: Endotoxin exposure limits

Country	Organization	Substance	OEL	Reference
Germany	Dutch Expert Committee on Occupational Safety (DECOS)	Endotoxins	90 EU/m^3	(106)
Netherlands	Committee of the Health Council of the Netherlands	Endotoxins	90 EU/m^3	(2)
	The International Commission on Occupational Health (ICOH)	Endotoxins	125 EU/m^3	(110)

Table 2.7: Frequency of adverse health symptom occurrence in relation to airborne level of β-glucans in indoor environments

Concentration of β-glucans: 0.1-5.2 ng/m^3	
Frequency of occurrence (%)	**Health effects**
2-30	Headache
5-35	Dry cough
11-45	Throat irritation
16-50	Nasal irritation
21-75	Fatigue

Source: Ławniczek-Wałczyk A, Górny RL (106).

Table 2.8: Occupational exposure limits for terpenes and turpentine

Country	Organization	Substance	OEL
Sweden	Swedish Work Environment Authority (Arbetsmilj¨overket)	Turpentine, α-pinene, β-pinene, 3-carene, limonene	OEL8h = 25 ppm OEL15min = 50 ppm
Norway	Norwegian Labour Inspection Authority (Arbeidstilsynet)	Turpentine, α-pinene, β-pinene, 3-carene, (-)-limonene (+)-limonene,	OEL8h = 25 ppm
Denmark	Danish Working Environment Authority (Arbejdstilsynet)	Turpentine, terpenes	OEL8h = 25 ppm
Finland	Ministry of Health and Social Affairs	Turpentine, (-)-limonene	OEL8h = 25 ppm OEL15min = 50 ppm
USA	Occupational Safety and Health Administration (OSHA)	Turpentine, α-pinene, β-pinene, 3-carene	OEL8h = 100 ppm
USA	ACGIH	Turpentine, α-pinene, β-pinene, 3-carene	OEL8h = 20 ppm

Source: Granstrom (109)

b) Workplace control measures

Several studies support the concept that exposure reduction is likely to be followed by a reduction in disease burden such as work-related asthma (97). While the use of personal protective equipment is generally considered to be the least effective measure in the hierarchy of control measures, sometimes there is no other choice, and the alternatives might not be available/possible.

The first intervention study conducted in Minnesota (USA), which included a combination of engineering, administrative, and behavioral components demonstrated that a combination of these measures can contribute to the reduction of level of exposure. The median dust concentration at baseline in the original study was 5.87 mg/m^3 among intervention workplaces and 6.23 mg/m^3 among comparison workplaces. One year later, the median dust concentrations was reduced to 4.71 mg/m^3 (reduction of 19.8%) and 5.58 mg/m^3 (reduction of 10.4%) from baseline in the intervention and comparison workplaces, respectively (111).

Schlünssen et al. (60) have suggested that in order to decrease the wood dust exposure level, focus should be on exhaust ventilation and cleaning methods. Strategies included ensuring effective local exhaust ventilation at all woodworking machines, professionalizing cleaning, avoiding the use of compressed air and increasing the use of vacuum cleaning. More recent studies by Douwes et al, have also demonstrated that local exhaust ventilation and the use of vacuum cleaners in joinery and furniture manufacturing reduced dust concentrations while specific tasks and work processes such as sanding, compressed air, hand tools, dry wiping and cleaning, and small workshops (<20 workers) were associated with increased wood dust exposures (96). The intervention study by Kohneshahri et al., (112) has also demonstrated that local exhaust ventilation systems are able to reduce toluene diisocyanate (TDI) and dust levels in woodworking industries. Prior to the implementation of the intervention, the emission concentrations in workstations were 0.0165 ± 0.0025 ppm for TDI and 0.42±0.01 mg/m^3 for total dust. These levels were significantly reduced dust after implementing the local exhaust ventilation system for both TDI (0.003± 0.0007 ppm) and total wood dust (0.15± 0.07 mg/m^3).

These are also alluded to in a series of measures proposed by the California Department of Public Health to reduce exposure to wood dust that include the use of “less toxic” woods, enclosure of machines, use of local exhaust ventilation for machines and tools, ventilation of working rooms, maintenance of tools, use of good work practices, practice of good housekeeping and good personal hygiene, proper disposal of waste and training of staff (113).

Since wood processing and joineries, especially in low- and middle-income countries (LMICs) are predominantly small scale in nature, there are various workplace organizational factors that can also impact on preventive activities. Hasle et al. (114) has suggested that small enterprises have special problems that need to be considered when designing interventions for the work environment. The risk is higher and the ability to control lower due to limited human and economic resources. Tools and methods aimed at small enterprises may include different types of checklists (including both risk assessment and more action oriented types), comprehensive health and safety management systems and accident prevention. The most successful methods seem to be action-oriented, combining health and safety with other management goals, and based on trust and dialogue.

c) Information, education and training

In a Nigerian study of timber workers Diwe et al., found that despite their increased awareness of occupational hazards, workers were unable to link the effects of the hazards they generally experienced with the lack of consistent use of appropriate PPE, and as such, they continued to remain exposed and at an increased risk of respiratory problems (115).

Awosan et al. (116) studying the knowledge of workplace hazards, safety practices and prevalence of workplace-related health problems among sawmill workers in Sokoto, Nigeria, also found high level of awareness of workplace hazards of sawmill workers (81.4%) among the respondents. However, less than two-thirds of workers (55.8%) had good knowledge of their workplace hazards, which the authors of study explained as result of low educational level (57% had primary education and below) and an even lower proportion (45%) had attended any training on occupational health and safety.

Assessment of injuries in the small scale sawmill industry conducted by Bello and Mijinyawa (117) in South Western Nigeria revealed that none of the workers had attended any health and safety training and that the knowledge they acquired was based on apprenticeship training and experience gathered on the job.

A recent study by Asgedom et al. (118) among temporary and permanent particleboard workers in Ethiopia revealed a higher proportion of positive responses on knowledge and attitude towards chemical health hazards among permanent compared with temporary workers. However, practice in use of PPE depended on access to PPE and few temporary workers were provided with PPE.

This points to the need for proper education of workers and managers on the relevant hazards associated with work in the industry, proper occupational hygiene practices and consistent use of the appropriate protective devices, through education and training programmes.

Studies done in other settings on occupational health and safety (OHS) training have also shown that workplace education and training programs have a positive impact on health and safety behaviours. However, OHS training as a lone intervention, without other control measures, has not been demonstrated to have an impact on health (119, 120, 121). Therefore, it is recommended to combine workplace education and training programs with other control measures.

2.11. CONCLUSION

This review of the literature has provided the body of evidence with regard to the association between wood dust exposure and asthma as it currently. However, it has identified some deficiencies that relate to methodological issues; lack of power due to small sample size; variable diagnostic criteria and epidemiological definitions for asthma; lack of objective markers of asthma including airway inflammatory markers; lack of information on the actual wood species used in the production processes; lack of detailed information about the concentrations of other agents present in wood dust such as endotoxins, glucans, terpenes and wood dust allergens. Despite the dose response relationships that have been reported, few studies have conducted a comprehensive assessment of dose-response relationships using both current and cumulative wood dust exposure metrics in relation to work-related respiratory symptoms, variable airway obstruction and inflammation among workers exposed to specific tropical woods in generally and specifically in the Mozambique wood processing industry.

Future studies should focus on better identification of the environmental risk factors for work-related asthma among wood workers through the quantification of wood allergen/endotoxin/glucan exposures, characterization of specific IgE responses to different wood species for which the pathophysiological mechanisms are better known, modelling of the dose response-relationship using exposure metrics beyond dust particulate to other associated agents, improved understanding of the pathophysiological mechanisms of wood dust related asthma, and harmonization of internationally exposure standards for wood dust species in general (hard and soft woods) as well as improved standards for endotoxins and β-glucans.

2.12. REFERENCES

1. Schlunssen V, Schaumburg I, Heederik D, Taudorf E et al. Indices of asthma among atopic and non-atopic woodworkers. Occup Environ Med. 2004;61(6):504–11.
2. Straumfors A, Olsen R, Hanne Daae HL, McLean D, Corbin M, et al. Exposure to Wood Dust, Microbial Components, and Terpenes in the Norwegian Sawmill Industry. Ann Work Expo Heal. 2018;20(20):1–15.
3. Asgedom AA, Bråtveit M, Moen BE. High prevalence of respiratory symptoms among particleboard workers in ethiopia: A cross-sectional study. Int J Environ Res Public Health. 2019;16(12):10.
4. Mumuni M. Respiratory Health Problems Among Sawmill Workers At the Timber Market , Accra. University of Ghana; 2015.
5. Chamba P, Nunes E. Work-related asthma among workers in the wood-processing industry: A review. Current Allergy and Clinical Immunology. 2016;29(2):110–7.
6. Gioffrè A, Marramao A, Iannò A. Airborne microorganisms, endotoxin, and dust concentration in wood factories in Italy. Ann Occup Hyg. 2012;56(2):161–9.
7. Alwis KU. Occupational exposure to wood dust. The University of Sydney; 1998.
8. Rongo LMB, Besselink A, Msamanga GI, Dolmans WM V, Demers PA, Heederik D. Respiratory symptoms and dust exposure among male workers in small-scale wood industries in Tanzania. J Occup Environ Med. 2002;44(12):1153–60.
9. Schluenssen V, Sigsgaard T, Raulf-Heimsoth M, Kespohl S. Workplace exposure to wood dust and the prevalence of wood-specific sensitization. Allergologie. 2012;35(8):402–12.
10. Afanou KA, Eduard W, Laier Johnsen HB, Straumfors A. Fungal fragments and fungal aerosol composition in sawmills. Ann Work Expo Heal. 2018;62(5):559–70.
11. Mandryk J, Alwis KU, Hocking AD. Effects of Personal Exposures on Pulmonary Function and Work-related Symptoms Among Sawmill Workers. Ann Occup Hyg. 2000;44(4):281–9.

12. Pérez-Ríos M, Ruano-Ravina A, Etminan M, Takkouche B. A meta-analysis on wood dust exposure and risk of asthma. Allergy. 2010;65(4):467–73.

13. Jacobsen GH, Schlünssen V, Schaumburg I, Sigsgaard T. Cross-shift and longitudinal changes in FEV_1 among wood dust exposed workers. Occup Environ Med. 2013;70(1):22–8.

14. Heikkilä P, Martikainen R, Kurppa K, Husgafvel-Pursiainen K, Karjalainen A. Asthma incidence in wood-processing industries in Finland in a registerbased population study. Scand J Work Environ Heal Suppl. 2008;34(1):66–72.

15. Jacobsen G, Schlünssen V, Schaumburg I, Sigsgaard T. Increased incidence of respiratory symptoms among female woodworkers exposed to dry wood. Eur Respir J. 2009;33(6):1268–76.

16. K. Hosseini D, Malekshahi Nejad V S, H, K. Hosseini H, Adeli SH WT. Prevalence of respiratory symptoms and spirometric changes among non-smoker male wood workers. PLoS One. 2020;15(3):1–11.

17. Demissie WR. Prevalence of Respiratory Disorders among Woodworkers in Jimma Town, Southwest Ethiopia. Pulm Med Respir Res. 2019;5(1):1–6.

18. Demissie RW. Assessment of Respiratory Symptoms among Woodworkers in Jimma Town, Southwest Ethiopia, A Comparative Cross-Sectional Study. Biomed J Sci Tech Res. 2019;18(2):13425–30.

19. Paraskevaidou K, Porpodis K, Kontakiotis T, Kioumis I, Spyratos D, Papakosta D. Asthma and rhinitis in Greek furniture workers. J Asthma. 2019;1–10.

20. Neghab M, Jabari Z, Kargar Shouroki F. Functional disorders of the lung and symptoms of respiratory disease associated with occupational inhalation exposure to wood dust in Iran. Epidemiol Health. 2018;40:8.

21. Chaiear N, Ngoencharee J, Saejiw N. Respiratory Symptoms and Pulmonary Function among Workers in a Rubber Wood Sawmill Factory in Thailand. Am J Public Heal Res. 2018;6(2):65–71.

22. Wiggans RE, Sumner J, Robinson E. Respiratory symptoms, lung function and sensitisation across different exposure groups of British woodworkers. Thorax. 2017;72(3):A1-278.

23. Tobin et al. Occupational Exposure to Wood Dust and Respiratory Health Status of Sawmill Workers in South-South Nigeria. Pollut Eff Control. 2016;4(1):4–9.

24. Nde F, Mbatchou H. Respiratory Symptoms and Pulmonary Function tests among Informal Sector Workers Exposed to Wood Dust in Douala, Cameroon. J Allergy Ther. 2015;06(06):8–11.

25. Soongkhang I, Laohasiriwong W. Respiratory tract problems among wood furniture manufacturing factory workers in the Northeast of Thailand. Kathmandu Univ Med J. 2015;13(50):125–9.

26. Nigisti A. Pulmonary Function Test And Pulseoximetry in Chip Wood Factory Workers Of Maichew, Tigray Region. Addis Ababa University; 2014.

27. Adeoye O, Adeomi A, Olugbenga-Bello A, Bamidele J, Abodunrin O, Sabageh O. Respiratory symptoms and peak expiratory flow among sawmill workers in south western Nigeria. J Environ Occup Sci. 2014;3(3):141.

28. Boskabady MH, Rezaiyan MK, Navabi I, Shafiei S, Arab SS. Work-related respiratory symptoms and pulmonary function tests in northeast iranian (the city of Mashhad) carpenters. Clinics. 2010;65(10):1003–7.

29. Ugheoke A. Prevalence of respiratory symptoms among sawmill workers in Benin City, Nigeria. Int J Trop Med. 2009;4(1):1–3.

30. Publio A. Prevalence of respiratory symptoms among furnture factory workers, in Votuporanga-SP. 2008.

31. Aguwa EN, Okeke TA, Asuzu MC. The prevalence of occupational asthma and rhinitis among woodworkers in south-eastern Nigeria. Tanzan Health Res Bull. 2007;9(1):52–5.

32. Fox FH. An Epidemiological Survey of Asthma in a Pine Sawmill in South Africa. 2004.

33. Arbak P. Respiratory Symptoms and Peak Expiratory Flow Rates Among Furniture - Decoration Students. Ann Agric Env Med. 2004;(11):13–7.

34. Borm PJ a, Jetten M, Hidayat S, van de Burgh N, Leunissen P, Kant I, et al. Respiratory symptoms, lung function, and nasal cellularity in Indonesian wood workers: a dose-response analysis. Occup Environ Med. 2002;59(5):338–44.

35. Milanowski J. Work-related symptoms among furniture factory workers in lublin region (Eastern Poland). Ann Agric Environ Med. 2002;9:99–103.

36. Schlünssen V, Schaumburg I, Taudorf E, Mikkelsen AB, Sigsgaard T. Respiratory symptoms and lung function among Danish woodworkers. J Occup Environ Med.

2002;44(1):82–98.

37. Douwes J, McLean D, Slater T, Pearce N. Asthma and other respiratory symptoms in New Zealand pine processing sawmill workers. Am J Ind Med. 2001;39(6):608–15.

38. Talini D, Monteverdi A, Benvenuti A, Petrozzino M, Di Pede F, Lemmi M, et al. Asthma-like symptoms, atopy, and bronchial responsiveness in furniture workers. Occup Environ Med. 1998;55(11):786–91.

39. Shamssain MH. Pulmonary function and symptoms in workers exposed to wood dust. Thorax. 1992;47(2):84–7.

40. Ngajilo D. Occupational contact urticaria and early-onset work-related asthma in a latex-allergic woodworker exposed to obeche wood. Curr Allergy Clin Immunol. 2018;31(4):184–9.

41. Lee LT, Tan KL. Occupational asthma due to exposure to chengal wood dust. Occup Med (Lond). 2009;59(5):357–9.

42. Algranti E, Mendonça EMC, Ali SA, Kokron CM, Raile V. Occupational asthma caused by Ipe (Tabebuia spp) dust. J Investig Allergol Clin Immunol. 2005;15(1):81–3.

43. Jeebhay MF, Prescott R, Potter PC, Sa FCP, Ehrlich RI, Sap F, et al. Brief communications Occupational asthma caused by imbuia wood dust. J Allergy Clin Immunol. 1996;1025–7.

44. Spiewak R. Occupational asthma due to wood dust exposure (ash, oak, beech and pine) - A case study. Ann Agric Env Med. 1994;6:73–6.

45. Cartier A et al. Occupational asthma caused by eastern white cedar (Thuja occidentalis) with demonstration that plicatic acid is present in this wood dust and is the causal agent. J Allergy Clin Immunol. 1986;77(4):639–45.

46. Hinojosa M, Moneo I, Dominguez J, Delgado E, Losada E, Alcover R. Asthma caused by African maple (Triplochiton scleroxylon) wood dust. J Allergy Clin Immunol. 1984 Feb;74(6):782–6.

47. Bush RK, Clayton D. Asthma due to Central American walnut (Juglans olanchana) dust. Clin Allergy. 1983;13(4):389–94.

48. Paggiaro PL, Cantalupi R, Filieri M, Loi a M, Parlanti a, Toma G, et al. Bronchial asthma due to inhaled wood dust: Tanganyika aningré. Clin Allergy. 1981 Nov;11(6):605–10.

49. Raghuprasad et al. Quillaja bark (soapbark)-induced asthma. J Allergy Clin Immunol. 1980;65(4):285–7.

50. Bush et al. Asthma due to African zebrawood (Microberlinia) dust. Vol. 3. 1978. p. 601–3.
51. Booth BH, Lefoldt RH, Mofrtt EM, Jacksox MD. Wood dust hypersensitivity. J Allergy Clin Immunol. 1976;57(4):352–7.
52. Chan-Yang and Abboud. Occupational asthma due to California red wood (Sequoia sempervirens) dusts. Am Rev Respir Dis. 1976;5:1027–31.
53. Howie AD, Boyd G, Moran F. Pulmonary hypersensitivity to Ramin (Gonystylus bancanus). Thorax. 1976;31:585–7.
54. Eaton KK. Respiratory allergy to exotic wood dust. Clin Allergy. 1973;3(3):307–10.
55. Pickering AC, Batten JC, Pepys J. Asthma due to inhaled wood dusts — Western red cedar and Iroko. Clin Allergy. 1972;2:213–8.
56. Gandevia B, Milne J. Occupational asthma and rhinitis due to Western red cedar (Thuja plicata), with special reference to bronchial reactivity. Brit J Ind Med. 1970;27(1949):235–44.
57. Sosman et al. Hypersensitivity to wood dust. N Engl J Med. 1969;281(18):977–80.
58. Teschke K, Demers PA, Davies HW, Kennedy SM, Marion SA, Leung V. Determinants of exposure to inhalable particulate, wood dust, resin acids, and monoterpenes in a lumber mill environment. Ann Occup Hyg. 1999;43(4):247–55.
59. Ronald LA, Davies HW, Bartlett KH, Kennedy SM, Teschke K, Spithoven J, et al. β (1 -3)-glucan exposure levels among workers in four british columbia sawmills. Ann Agric Env Med. 2003;10:21–9.
60. Schlunssen V, Jacobsen G, Erlandsen M, Anders B. Mikkelsen IS and Sigsgaard T. Determinants of Wood Dust Exposure in the Danish Furniture Industry — Results from Two Cross-Sectional Studies 6 Years Apart Determinants of Wood Dust Exposure in the Danish Furniture Industry — Results from Two Cross-Sectional Studies 6 Years Apart. Ann Occup Hyg. 2008;52(4):227–38.
61. Douwes J, Cheung K, Prezant B, Sharp M, Corbin M, McLean D, et al. Wood dust in joineries and furniture manufacturing: An exposure determinant and intervention study. Ann Work Expo Heal. 2017;61(4):416–28.
62. Asgedom AA, Bråtveit M, Schlünssen V, Moen BE. Exposure to inhalable dust, endotoxin and formaldehyde in factories processing particleboards from eucalyptus trees in Ethiopia. Env Occup Heal Pract. 2020;1–10.
63. Ayalew E, Gebre Y, De Wael K. A survey of occupational exposure to inhalable wood dust among workers in small-and medium-scale wood-processing enterprises in Ethiopia. Ann Occup Hyg. 2015;59(2):253–7.
64. Klarić MŠ, Varnai VM, Čalušić AL, Macan J. Occupational exposure to airborne fungi in two Croatian sawmills and atopy in exposed workers. Ann Agric Environ Med.

2012;19(2):213–9.

65. Hagström K, Jacobsen G, Sigsgaard T, Schaumburg I, Erlandsen M, Schlunssen V. Predictors of monoterpene exposure in the Danish furniture industry. Ann Occup Hyg. 2012;56(3):253–63.

66. Osman E, Pala K. Occupational exposure to wood dust and health effects on the respiratory system in a minor industrial estate in Bursa, Turkey. Int J Occup Med Environ Health. 2009;22(1):43–50.

67. Hagström K, Axelsson S, Arvidsson H, Bryngelsson I, Eriksson K, Hagstr K. Exposure to Wood Dust , Resin Acids , and Volatile Organic Compounds During Production of Wood Pellets. J Occup Environ Hyg. 2008;5:296–304.

68. Spee T, van de Rijdt-van Hoof E, van Hoof W, Noy D, Kromhout H. Exposure to wood dust among carpenters in the construction industry in the Netherlands. Ann Occup Hyg. 2007;51(3):241–8.

69. Douwes J, Mclean D, Slater T, Travier N, Cheng S, Pearce N. Pine dust, atopy and lung function: a cross- sectional study in sawmill workers. Eur Respir J. 2006;28:791–8.

70. Rongo LMB, Msamanga GI, Burstyn I, Barten F, Dolmans WM V, Heederik D. Exposure to wood dust and endotoxin in small-scale wood industries in Tanzania. J Expo Anal Environ Epidemiol. 2004;14(7):544–50.

71. Krysinska et al. Exposure to airborne microorganisms in furniture factories. Ann Agric Env Med. 2002;9:85–90.

72. Dutkiewicz J, Krysinska-Traczyk E, Prazmo Z, Skorska C SJ. Exposure to airborne microorganisms in Polish sawmills. Ann Agric Env Med. 2001;8:71–80.

73. Eriksson KA, Stjernberg NL, Levin JO, Hammarström U, Ledin MC. Terpene exposure and respiratory effects among sawmill workers. Scand J Work Env Heal. 1996;22(3):182–90.

74. Meo SA. Effects of duration of exposure to wood dust on peak expiratory flow rate among workers in small scale wood industries. Int J Occup Med Environ Health. 2004;17(4):451–5.

75. De Matteis S, Jarvis D, Darnton A, Hutchings S, Sadhra S, Fishwick D, et al. The occupations at increased risk of COPD: analysis of lifetime job-histories in the population-based UK Biobank Cohort. Eur Respir J. 2019;54(1):9.

76. Jacobsen G, Schaumburg I, Sigsgaard T. Non-malignant respiratory diseases and occupational exposure to wood dust. Part I. Fresh wood and mixed wood industry. Ann Agric Environ Med. 2010;17:15–28.

77. Hannu T, Lindström I, Palmroos P, Kuuliala O, Sauni R. Prediction of obeche wood-induced asthma by specific skin prick testing. Occup Med (Chic Ill). 2013;63:429–31.

78. Wiggans RE, Evans G, Fishwick D, Barber CM. A study of dynamic lung function tests in saw mill workers of bijapur city. Occup Med (Chic Ill). 2016;66:193–201.
79. Kespohl S, Ochmann U, Maryska S, Nowak D, Brüning T. Diagnostic algorithm for IgE-mediated wood dust allergy. Allergol Int. 2016;39(4):168–74.
80. Vandenplas O, Godet J, Hurdubaea L, Rifflart C, Suojalehto H, Wiszniewska M, et al. Are high - and low - molecular - weight sensitizing agents associated with different clinical phenotypes of occupational asthma ? Allergy. 2019;74:261–72.
81. Tarlo SM and Lemiere C. Occupational asthma. N Engl J Med. 2014;370:640–9.
82. Pylkkänen L, Stockmann-Juvala H, Alenius H, Husgafvel-Pursiainen K, Savolainen K. Wood dusts induce the production of reactive oxygen species and caspase-3 activity in human bronchial epithelial cells. Toxicology. 2009;262(3):265–70.
83. Lytras T, Kogevinas M, Kromhout H, Carsin A-E, Antó JM, Bentouhami H, et al. Occupational exposures and 20-year incidence of COPD: the European Community Respiratory Health Survey. Thorax. 2018;0:1–8.
84. Kespohl S., Sander I., Schulze J., Poppe M., Brüning T., Raulf-Heimsoth M. Development of an obeche wood allergen quantification assay for the assessment of allergen exposure in workplaces. Scand J Work Environ Heal. 2008;34(5):387–95.
85. Jeebhay MF, Quirce S. Occupational asthma in the developing and industrialised world: A review. Vol. 11, International Journal of Tuberculosis and Lung Disease. 2007. p. 122–33.
86. Tamari M, ShotaTanaka, Hirota T. Genome-Wide Association Studies of Allergic Diseases. Allergol Int. 2013;62(1):21–8.
87. Demenais et al. Multiancestry association study identifies new asthma risk loci that colocalize with immune cell enhancer marks. Nat Gene. 2018;50(1):42–53.
88. Jeebhay and Adewole. Work-Related Asthma (WRA). AOEC. 2012;1:93–108.
89. Moscato G, Vandenplas O, Van Wijk RG, Malo J-L, Perfetti L, Quirce S, et al. EAACI position paper on occupational rhinitis. Respir Res. 2009;10:16.
90. Jeebhay, M. F. and Adewole OO. Work-Related Asthma (WRA). AOEC. 2012;(1):93–108.
91. Ugheoke AJ, Ebomoyi MI, Iyawe VI. Influence of smoking on respiratory symptoms and lung function indices in sawmill workers in Benin City, Nigeria. Niger J Physiol Sci. 2006;21(1–2):49–54.
92. Bolund ACS, Miller MR, Jacobsen GH, Sigsgaard T, Schlünssen V. New-onset COPD and Decline in Lung Function Among Wood Dust-Exposed Workers : Re-analysis of a 6-year Follow-up Study. Ann Work Expo Heal. 2018;20(20):1–13.
93. Moscato G, Apfelbacher C, Brockow K, Eberle C, Genuneit J, Mortz CG, et al. Gender and occupational allergy: Report from the task force of the EAACI Environmental and

Occupational Allergy Interest Group. Allergy Eur J Allergy Clin Immunol. 2020;75(11):2753–63.
94. Mandryk J, Alwis KU, Hocking AD. Work-related symptoms and dose-response relationships for personal exposures and pulmonary function among woodworkers. Am J Ind Med. 1999;35(5):481–90.
95. Mikkelsen AB. Determinants of Wood Dust Exposure in the Danish Furniture Industry. Ann Occup Hyg. 2002;46(8):673–85.
96. Douwes J. Wood dust in joineries and furniture manufacturing: an exposure determinant and intervention study. Ann Work Expo Heal. 2017;61(4):416–28.
97. Heederik D, Henneberger PK, Redlich CA. Primary prevention: exposure reduction, skin exposure and respiratory protection. Eur Respir Rev. 2012;21(124):112–24.
98. SCOEL. Methodology for the Derivation of Occupational Exposure Limits. Eur Comm. 2013;76:1–38.
99. ACGIH. Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs). 2012. 871–1130 p.
100. Australia SW. Workplace exposure standards for airborne contaminants. 2018. 43 p.
101. The Swedish Work Environment Authority. Occupational Exposure Limit Values. 2011. 84 p.
102. Kauppinen T, Vincent R, Liukkonen T, Grzebyk M, Kauppinen A, Welling I, et al. Occupational Exposure to Inhalable Wood Dust in the Member States of the European Union. Ann Occup Hyg. 2006;50(6):549–61.
103. Kesteren PCE Van, Palmen NGM, Dekkers S. Occupational Exposure Limits and classification of 25 carcinogens Occupational. 2012. 49 p.
104. Government NZ. Workplace Exposure Standards and Biological Exposure Indices. 2018. 68 p.
105. SMI Analytical. Occupational Exposure limits in South Africa. 2006.
106. Ławniczek-wałczyk A, Górny RL. Endotoxins and β-glucans as markers of microbiological contamination – characteristics, detection, and environmental exposure. Ann Agric Env Med. 2010;17:193–208.
107. Rylander R. Indoor Air-Related Effects and Airborne (1→3)-β-D-Glucan. Environ Health Perspect. 1999;107(3):501–3.
108. Straumfors A, Olsen R, Daae HL, Afanou A, Mclean D, Corbin M, et al. Exposure to Wood Dust , Microbial Components , and Terpenes in the Norwegian Sawmill Industry. Ann Work Expo Heal. 2018;20(20):1–15.
109. Granström KM. Underestimation of terpene exposure in the Nordic wood industry. J Occup Environ Hyg [Internet]. 2010;7(3):144–51
110. Pipinić IS, Varnai VM, Lučić RB, Čavlović A, Prester L, Orct T, et al. Endotoxin

exposure assessment in wood-processing industry: Airborne versus settled dust levels. Arh Hig Rada Toksikol. 2010;61(2):161–6.

111. Lazovich D, Parker DL, Brosseau LM, Milton FT, Dugan SK, Pan W, et al. Effectiveness of a worksite intervention to reduce an occupational exposure: the Minnesota wood dust study. Am J Public Health. 2002;92(9):1498–505.

112. Kohneshahri MH, Mohammadyan M, Khani HM, Pourhossein M, Dastakzan B. Designing a Local Exhaust Ventilation System to Control Toluene Diisocyanate and Dust in Woodworking Industries. Int J Occup Hyg. 2008;8(4):223–9.

113. California Department of Public Health. Wood Dust and Work-related Asthma. 2017.

114. Hasle P, Limborg HJ. A review of the literature on preventive occupational health and safety activities in small enterprises. Ind Health. 2006;44(1):6–12.

115. Diwe KC, Duru CB, Iwu AC, Merenu IA, Uwakwe KA, Oluoha UR, et al. Occupational Hazards , Safety and Hygienic Practices among Timber Workers in a South Eastern State , Nigeria. Occup Dis Environ Medicice. 2016;4:63–71.

116. Awosan KJ, Ibrahim MTO, Yunusa EU, Isah BA, Ango UM, Michael A. Knowledge of Workplace Hazards, Safety Practices and Prevalence of Workplace-related Health Problems among Sawmill Workers in Sokoto, Nigeria. Int J Contemp Med Res [IJCMR]. 2018;5(10):5–12.

117. Bello SR, Mijinyawa Y. Assessment of Injuries in Small Scale Sawmill Industry of South Western Nigeriall. Agric Eng Int CIGR J Sci Res Dev Manuscr 1558. 2010;XII:1–11.

118. Asgedom AA, Bråtveit M, Moen BE. Knowledge, attitude and practice related to chemical hazards and personal protective equipment among particleboard workers in Ethiopia: A cross-sectional study. BMC Public Health. 2019;19(1):1–10.

119. Cohen A, Colligan MJ, Sinclair R, Newman J, Schuler R. Assessing occupational safety and health training: A literature review. Cincinnati, OH Natl Institutes Heal. 1998;1–174.

120. Robson AL, Stephenson C, Schulte P, Amick B, Chan S, Clarke J, et al. A systematic review of the effectiveness of training & education for the protection of workers. Institute for Work & Health. 2010;1–148.

121. Robson LS, Stephenson CM, Schulte PA, Amick BC, Irvin EL, Eggerth DE, et al. A systematic review of the effectiveness of occupational health and safety training. Scand J Work Environ Health. 2012; 38:193–208.

CHAPTER 3

METHODS

3.1 ELEMENTS OF THE STUDY

3.1.1 Study design

This was a cross-sectional study of wood workers in the furniture/joinery industry in Mozambique conducted during the period 2016 – 2019. Due to logistical and resource considerations a cross-sectional study was considered to be the most pragmatic in this setting.

3.1.2 Study population

The study population entailed workers that were working in 21 factories in the provinces of Maputo City, Maputo Province and Sofala Province of Mozambique. A total of 450 among the 513 workers participated in the study and were employed in wood processing departments (n = 394) and as office workers (n = 56), representing an overall 88% response rate. The study design considered geographical distribution of the factories (inland versus coastal) to take into consideration whether this would impact on the dust components produced during processing. For instance, Kespohl et al. (2) has shown that same type of wood species (obeche wood), depending on their origin (Cameroon or Ghana) had different allergen content. Ronald et al. (3) studying the determinants of β-glucans exposure among workers in four British Columbia sawmills also found higher overall β-glucan levels in the mills located in the interior compared to mills located on the coast. These studies suggest that geographical location of the factory may be an important determinant of exposure to processed wood.

The study population were employed in Maputo City having 142 furniture/joinery workers employed in 12 factories, Maputo Province with 76 workers employed in 3 factories and Sofala Province with 232 furniture/joinery workers employed in 6 factories.

Table 3.1 illustrates the distribution of workers employed in relation to the wood species used in each of the wood processing factories. Whilst workers were exposed to different wood species, the study evaluated the effect of individual indigenous wood species as significant predictors/determinants of exposure variability and risk factors for asthma phenotypes. The study did not focus on a possible interaction or combined effect of working with different species as this has not been previously reported.

3.1.3 Sample size considerations

There are no published studies on the prevalence of asthma in workers exposed to wood dust in Mozambique. To calculate the sample size the prevalence data of asthma among workers exposed to wood dust in Africa of between 3 and 7% was used. Taking as reference the prevalence of 7% (mean), the prevalence of asthma among highly exposed workers based on the review (1) would have been about 10% and in the least exposed 5%. To detect a difference of 5% among highly exposed workers and least exposed workers, a sample size of 435 workers was required for the study to have a power of 80% with $\alpha = 0.05$. Given that 450 workers finally participated in the study, there was reasonably sufficient power for testing the hypotheses that exposure to wood dust is associated with an increased risk of asthma and rhinitis.

3.1.4 Study components

Employers of the selected factories were contacted, and permission sought to address the workers prior to the fieldwork. A meeting was arranged to explain the purpose of the study and provide each with an information sheet containing details of study and a consent form (Appendix 1). Those who agreed to participateunderwent the tests at the work site during work time.

Figure 3.1 presents the various elements of the study components. The study was divided into two main arms viz. exposure assessment and health outcome assessment. In the exposure assessment arm, personal environmental samples were collected to determine the concentration of wood dust particulate, endotoxins and glucans in various jobs. The health outcome assessment involved the use of a standardised ECRHS questionnaire, fractional exhaled nitric oxide, spirometry with post-bronchodilator response and a Phadiatop blood test.

Table 3.1: Details of participating Mozambiquan wood processing factories in relation to wood species processed

Factory	No. of workers	Province	Wood species																					
			MB	**AT**	**PP**	**LIW**	**AM**	**AS**	**P**	**MT**	**ZW**	**MS**	**MSS**	**PR**	**MG**	**MC**	**NT**	**MO**	**CHC**	**NC**	**MCH**	**ME**	**E**	**F**
SECAMA	21	MP	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yola	11	MP	x	x	x	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Luxoflex	44	MP	x	x	x	-	x	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SB	11	MC	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FERSOL	24	MC	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Simbine	8	MC	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manguele	18	MC	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nwavele	10	MC	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
ERFI	11	MC	x	x	x	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Langa	11	MC	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marrengule	13	MC	x	x	x	x	x	-	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Repinga	7	MC	x	x	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Muda Carp	7	MC	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Comiche	18	MC	x	x	x	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Machanguane	5	MC	x	x	x	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IMM Wood Process	29	SP	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-
IMM Florestal Concession	22	SP	x	x	x	x	x	x	x	x	-	x	x	-	-	-	-	-	-	x	x	-	x	-
Mutende	28	SP	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-
Movarte	32	SP	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-
Fim da Vida	19	SP	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-
Levasflor	78	SP	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-	-
MPM	24	SP	x	x	x	x	x	x	x	x	-	x	x	-	-	-	-	-	-	x	x	x	-	-
Total	**450**																							

Provinces: MP: Maputo province, MC: Maputo City, SP: Sofala province

Wood species: MB: Mahogany bean (*Afzelia quanzensis Welw*); AT: African Teak (*Pterocarpus angolensis DC*); PP: Panga-panga (*Millettia Stuhlmannii Taub*); LIW: Lebombo Iron Wood (*Androstacys johnsonii Prain*); AM: African Mahogany (*Khaya nyasica Stapf*); AS: African sandalwood (*Spirostachys Africana Sonder*); P: Pine (*Pinus sp*); MT: Mutondo (*Cordyla Africana*); ZW: Zebrawood (*Microberlinia brazzavillensis*); MS: Missanda (*Erythrophleum suaveolens Brenan*); MSS: Messassa (*Brachystegia spiciformis Benth.*); PR: Pau-rosa (*Berchemia zeyheri (Klotzch) Hemsley*); MG: Mugonha (*Breonadia microcephala Ridsd*.); MC: Mucarala (*Burkea africana Hook.*); NT: Ntholo (*Pseudolachnostylis maprouneifolia Pax*); MO: Mondzo (*Combretum imberbe Wawra.*); CHC: Chacate (*Guibourita conjugate (Bolle) J.Leonard*); NC: Ncula (*Pterocarpus tinctorious Welw.*); MCH: Metacha (*Berchemia discolour (Klotzsch) Hemsley*); ME: Mepepe (*Albizia adianthifolia W.F.Wight*); E: Ebano *(Dyospiros mespiliformis Hochst.*); F: Medium-density fiberboard (*MDF*)

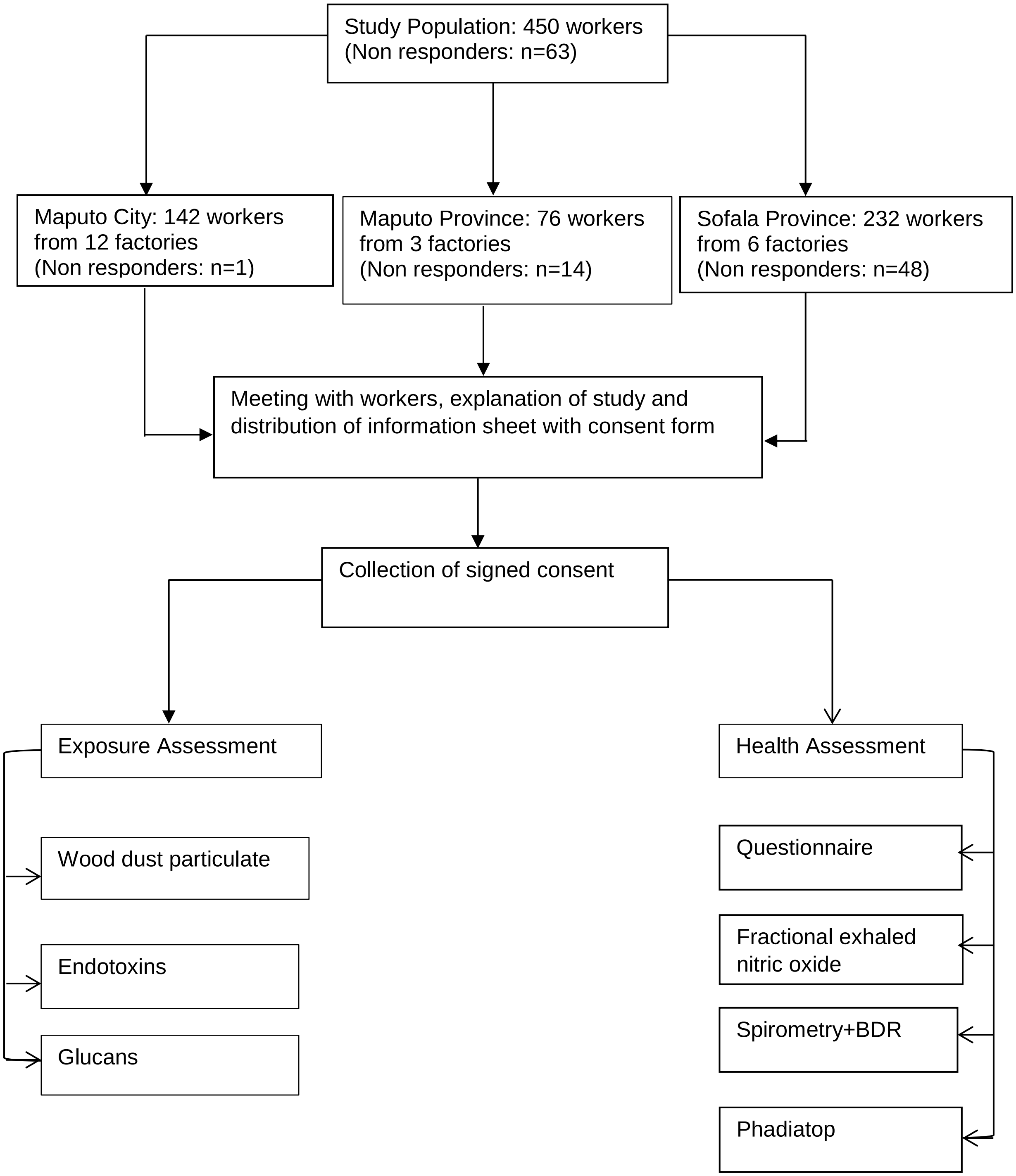


Figure 3.1: Study population and components of the study

3.2 WALK-THROUGH SURVEY

A walk-through inspection was conducted in each factory to assess the work processes and to obtain more detailed information with regard to work tasks, wood species used, state of woods processed, building characteristics and specific control measures implemented to reduce wood dust exposures in each factory. The checklist also included questions on: building design (open, semi-closed, closed), presence and type of ventilation system, wood dust cleaning methods (wet or dry), frequency or cleaning, waste disposal and whether workers had received education and training. The checklist used in this study was adapted from previous studies on bakery workers conducted by the collaborating study team (Appendix 7). The inspections were conducted during working time by a team that included an occupational hygienist and occupational medicine physician. During the walk-through inspection, each member of the team conducted their own independent evaluation and interviews with factory managers and worker representatives. The individual findings of each team member were discussed, and consensus reached about the final recording on the checklist.

Based on the information in Table 2, most factory workplaces (n=17, 77%) processed both dry and fresh woods, while only four (18%) companies processed dry wood and one (5%) exclusively handled fresh wood.

Generally, workers using drilling, planing and sanding machines appeared to have visibly very high wood dust exposures, compared to workers using sawing or carving machines and those in cleaning workshops. Workers involved in machine repairing, upholstering, manual sawing and setting had visibly reduced wood dust exposures. These observations were used to categorise workers into similar EGs (SEGs) (5) .

Table 3.2: Geographical locations, demographic details and nature of wood species processed in Mozambiquan factories studied

Province	Location	Factory	No. of workers	Wood species*	Physical state of wood: Dry	Fresh
Maputo	Matola	SECAMA	21	MB	Yes	Yes
Maputo	Matola	Yola	23	MB, AT, P	Yes	Yes
Maputo	Matola	Luxoflex	46	MB, AT,PP	Yes	Yes
Maputo City	Maputo	SB	11	MB, AT,PP,LIW,P	Yes	Yes
Maputo City	Maputo	FERSOL	24	MB, AT, PP, LIW, AM, AS, P	Yes	Yes
Maputo City	Maputo	Simbine	8	MB, AT, PP, LIW, AM, AS, P	Yes	Yes
Maputo City	Maputo	Manguele	18	MB, AT, PP, LIW, AM, AS, P	Yes	Yes
Maputo City	Maputo	Nwavele	10	MB, AT, PP, LIW, P	Yes	Yes
Maputo City	Maputo	ERFI	11	MB, AT, PP, LIW, P	Yes	Yes
Maputo City	Maputo	Langa	11	MB, AT, PP, LIW, P	Yes	Yes
Maputo City	Maputo	Marrengule	13	MB, AT, PP, LIW, AM, P	Yes	No
Maputo City	Maputo	Repinga	7	MB, AT, PP, LIW, AM, AS, P	Yes	Yes
Maputo City	Maputo	Muda Carp	7	MB, AT, PP, LIW, P	Yes	No
Maputo City	Maputo	Comiche	18	MB, AT, PP, AM, P	Yes	No
Maputo City	Maputo	Machanguane	5	MB, AT, PP, P	Yes	Yes
Sofala	Beira	IMM Wood Process	30	MB, AT, PP, ZW	Yes	Yes
Sofala	Cheringoma	IMM Florestal Concession	22	MB, AT, PP, MT,ZW	No	Yes
Sofala	Beira	Mutende	30	MB, AT, PP, MT	Yes	Yes
Sofala	Beira	Movarte	34	MB, AT, PP, MT,ZW	Yes	No
Sofala	Beira	Fim da Vida	19	MB, AT, PP, P, MS	Yes	Yes
Sofala	Cheringoma	Levasflor	121	MB, AT, PP, LIW, AM, MT,MS, MSS	Yes	Yes
Sofala	Beira	MPM	24	MB, AT, PP, LIW, AS, P, MT, MS, MSS	Yes	Yes

* Wood species processed: MB - (*Mahogany bean*); AT - (*African Teak*); PP - (*Panga-panga*); LIW - (*Lebombo Iron Wood*); AM - (*African Mahogany*); AS - (*African sandalwood*); MT - (*Mutondo*); ZW - (*Zebrawood*); MS - (*Missanda*); MSS - (*Messassa*); P - (*Pine*)

3.3 EXPOSURE ASSESSMENT

3.3.1 MEASUREMENT OF WOOD DUST, ENDOTOXINS AND GLUCANS EXPOSURE IN THE AIR

An environmental exposure assessment study of workers currently employed in the wood processing factories was conducted.

a) Study population

The study population comprised workers from nine wood processing factories within three provinces of Mozambique. The factories had an average of 43 employees (range: 11 – 121) currently working on site. The factories were randomly selected based on location, size and building design. Within each factory, workers in seven job titles could be distinguished viz: planer, sawyer, driller, machine repairer, sander, painter and upholsterer. Workers performing similar jobs were grouped into six similar exposure groups (SEGs).

Personal environmental sampling was performed on selected study subjects during five consecutive days (from Monday to Friday). Environmental samples were collected from the same worker during the work shift (Appendixes 8 – 10).

A total sample of 30 workers were randomly selected from six SEGs (similar exposure group) during the workshift to participate in the environmental dust measurement sampling. A total of 124 environmental samples were finally collected.

b) Personal wood dust sampling measurements

Full-shift inhalable dust samples were collected on each participating worker using a PAS6 sampling head (6) placed in the breathing zone and connected to a Gillian Gil Air pump with constant-flow calibrated at 2 litres per minute. The volume of air sampled was calculated based on the flow rate and duration of sampling. Teflon filters (Millipore; pore size 1.0 µm, 25 mm diameter) mounted in the sampling head were used to collect the wood dust. Filters were weighed before and after sampling using a microbalance (Mettler Toledo AG245) with 0.01 mg readability. Filters were acclimatized prior to weighing for 24 hours in a room with constant relative humidity (35%), temperature (22.6ºC) and air pressure 1019mbar to ensure standard weighing conditions. Sampling heads containing filters were kept in sterile plastic bags to avoid contamination. Dust samples were stored at -20^{o} C with moisture absorbent paper immediately after collection until further processing. In addition, one field blank was collected per each shift per day to control for cross contamination. Workers were observed throughout the shift and detailed information on tasks performed and specific work practices followed were recorded during personal environmental sampling (Appendix 10). The limit of detection (LOD) for the dust was 0.08 mg, calculated using the average weight difference of the blank filters plus three times the standard deviation. None of the samples collected had values below the LOD for total dust particulate. The results of dust measurements were recorded on the environmental data collection sheet 2 (Appendix 9).

The exposure assessment was overseen by Prof. Antonio Cumbane of Department of Chemical Engineering of Eduardo Mondlane University while the laboratory analysis of samples for endotoxins and glucans was conducted by Dr. Tanusha Singh at the National Institute for Occupational Health (NIOH) in South Africa.

c) Analysis of samples for endotoxins and glucans.

Endotoxins

For extraction and analysis of endotoxins filters were immersed in 5 ml of pyrogen- free water plus Tween 20 (0.05% v/v). After shaking for 60 min on a horizontal shaker, the tubes were centrifuged for 15 min at 1000 g (2094 rpm). Supernatants were harvested and stored in 0.1 ml aliquots at -20^{o}C until analysis. The endotoxins concentration was determined in supernatant using an endpoint chromogenic Limulus amebocyte lysate (LAL) method Lonza, Walkersville, USA. For each assay, a standard curve of an Escherichia coli standard obtained by the supplier was created in the concentration range 0.1– 1.0 EU ml^{-1} (10 EU = 1.0 ng) (7). The results were estimated as endotoxins units per cubic meter (EU m^{-3}).

(1-3)-β-D-Glucans

Following extraction for endotoxins, the aliquot was diluted two-fold with pyrogen free water with 0.05% Tween 20 and heat treated by autoclaving at 120°C for 1 hour before (1-3)-β-D-glucans determination. The (1-3)-ß-D-glucans was assayed using the Glucatell assay (Associates of Cape Cod, East Falmouth, MA, USA). The detection limit for (1-3) β-D-glucans was 20 pg/ml

(8). All dust samples were analyzed in duplicate. The (1-3)-β-D-glucans levels were expressed as ng m^{-3}.

3.4 HEALTH OUTCOME ASSESSMENT

The health outcome assessment entailed an interviewer-administered questionnaire, exhaled nitric oxide (FeNO), spirometry accompanied by bronchial reversibility testing and allergy testing (Phadiatop).

3.4.1 Questionnaire

Each worker completed a standard interviewer-administered questionnaire of the European Community Respiratory Health Survey (ECRHS) for the investigation of asthma (9, 10). The questionnaire was modified to include questions relating to current and previous employment, exposure to wood dust, types of wood the worker is exposed to, information regarding the origin of the wood species processed, detail on chemical and pesticide treatment (Appendix 3).

The questionnaire was translated into Portuguese and back translated to English to verify translation correctness. Interviews in Maputo City and Maputo Province were conducted by recently graduated physicians from Faculty of Medicine of Eduardo Mondlane University and in Sofala Province by a nurse and preventive medicine technician, all of whom received appropriate training prior to the study. Smoking status was classified into three categories: non-smoker as lifelong abstinence from smoking; ex-smoker if ceased smoking completely more than 1-month before the survey; and current smoker. Symptom variables included respiratory (wheeze and tightness in the chest, shortness of breath, cough and phlegm from the chest) and nasal (runny nose, blocked nose, stuffy nose) symptoms.

An asthma symptom score was computed based on the sum of answers (0=no, 1=yes) to five questions on asthma-like symptoms in the past 12 months (short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath), as has been described previously (11, 12). A binary variable was created from these five asthma-like symptoms (≥ 2 symptoms vs 0-1 symptom). Having ≥ 2 asthma-like symptoms was considered ‘more symptomatic’ and 0-1 asthma-like symptom ‘less symptomatic’.

Work-related asthma was defined as having an asthma attack in the past 12 months, current use of asthma medication or woken up by an attack of shortness of breath in the past 12 months; and work-related chest symptoms in the past 12 months that gets better when away from work or worsen on return to work.

Occupational rhinitis was defined as work-related specific symptom/s such as nasal congestion, itching, sneezing and rhinorrhea

3.4.2 Test for atopy (Phadiatop)

A blood sample (9 ml) was drawn from each participant using a Becton Dickinson Vacutainer SST tube (with gel medium and clot activator) bya qualified laboratory technologist. The blood was allowed to clot for 1-2 hours at room temperature (20-24 degrees Celsius) and then centrifuged at 1350 rpm for 10 minutes at room temperature at the Laboratory of the Centre of Medical Examinations of Maputo (for the samples collected in Maputo City and Maputo Province) and at the Laboratory of Medical Centre of Munhava and Medical Centre of Muanza (for the samples collected in Sofala Province). The sera were then transferred into micro-vials and stored at -70 degrees Celsius at the Laboratory of Central Hospital of Maputo (for the samples collected in Maputo City and Maputo Province). The serum samples collected in Sofala Province were initially stored at -20 degrees Celsius at the Laboratory of Medical Centre of Ponta Gea in Beira City and then transported on dry ice to Maputo City where they were stored at -70 degrees Celsius at the Laboratory of Central Hospital until they were analyzed further. The stored serum samples were then finally transported on dry ice to the University of Cape Town laboratories where they were stored at minus 80 degrees Celsius prior to being couriered to the SANAS accredited (ISO 15189:2007), National Institute for Occupational Health (NIOH) Immunology laboratory for further analysis. A material transfer agreement (MTA) between the author of the study and the UCT was signed (Appendix 11). The presence of sensitization to common aeroallergens (house dust mites, grass pollens, cat, dog, and cockroach) was determined using the Phadiatop® test (Phadia AB, Uppsala, Sweden), as it has been used extensively in evaluation of common inhalant allergy of individuals residing in the Southern African region, since it has a high degree of sensitivity for detecting atopy. A positive result was classified as any value ≥0.35 ku/L. Preliminary in vivo immunological studies of sera obtained from symptomatic workers to the commonly processed wood species by workers were unable to demonstrate IgE responses to these woods.

3.4.3 Spirometry and post-bronchodilator response (PBR)

Spirometry accompanied by bronchodilator challenge was considered to be the simplest technique with well established objective outcomes to use in this setting to identify individuals with underlying asthma. All workers were subjected to spirometry following American Thoracic Society (ATS)/ERS guidelines for conducting spirometry (13). The EasyOne Spirometer was used. It utilizes digital ultrasonic flow measurement technology, repeatable performance and quality control without the need for calibration or maintenance, thereby ensuring accurate results. Recently graduated physicians, a nurse and preventive medicine technician conducted the spirometry after undergoing training to ensure good quality spirograms. An average of 10 workers underwent spirometry each day. Spirometry was performed in a sitting position without nose clips. Each worker performed up to eight trials to produce three acceptable curves. Test reproducibility was used as a guide to whether further attempts were necessary. A quality control sheet was used to assess the quality of spirograms before the data was analysed. The information outlined in Table 3 presents the ATS/ERS quality categories that were used (14). Poor reproducibility may also be an independent marker of airway dysfunction, hence all spirometry tests with ATS quality grade F were not included in the analysis.

Table 3.3: Grading System for FEV_1 and FVC (Graded Separately)

Grade	Number of measurements	Repeatability: Age >6 yr
A	≥3 acceptable	Within 0.150 L
B	2 acceptable	Within 0.150 L
C	≥2 acceptable	Within 0.200 L
D	≥2 acceptable	Within 0.250 L
E	≥2 acceptable	>0.250 L
	OR 1 acceptable	Note applicable
U	0 acceptable AND ≥1 usable	Note applicable
F	0 acceptable and 0 usable	Note applicable

Source: ATS/ERS (2019) (14).

The lung function indices of primary interest included forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1). The best FEV_1 and FVC were used regardless of whether they belonged to the same tracing. The GLI-2012 reference values were used for spirometry interpretation, with lower limits corresponding to the 95th percentile (15). Heights and weights of workers were recorded for calculating predicted lung function indices using GLI equations. The timing of spirometry was during the working day from Monday to Friday. Special instructions to workers to ensure that tested individuals did not smoke tobacco (at least 2 hours before) nor did they take any anti-asthmatic inhalers (12 hours before) or oral asthma medications (48 hours before) prior to the test (Appendix 4). The results of spirometry and BDR tests were recorded on lung function test data collection sheets (Appendix 5). The BDR response was analysed using two approaches as described previously (16, 17).

3.4.4 Fractional Exhaled Nitric Oxide (FeNO)

The instantaneous on-line exhaled fractional exhaled nitric oxide (FeNO) monitoring method was performed according ATS/ERS recommendations for standardized measurement of exhaled nitric oxide levels (18). The recommended technique for adult patients involved inspiration of NO-free air via a mouthpiece to total lung capacity, followed immediately by full exhalation at an even rate through the mouthpiece into the apparatus. A hand-held portable nitric oxide sampling device (NIOX MINO® Airway Inflammation Monitor (NIOX MINO); Aerocrine AB, Solna, Sweden) was used for this purpose. The fieldworkers were trained to conduct the FeNO measurements prior to the study. The worker was seated comfortably, with the mouthpiece at the proper height and position. A nose clip was not used as this may allow nasal NO to accumulate and promote leakage of this NO via the posterior nasopharynx. The worker inserted a mouthpiece and inhaled over 2 to 3 seconds through the mouth to total lung capacity (TLC), and then exhaled immediately, since breath holding could affect FeNO. Two technically adequate measurements were performed. If the measurements differed by 10ppb or more, a third measurement was performed, and the mean of all three measurements was used.

Special instructions were provided to workers to ensure that tested individuals did not smoke tobacco, eat or drink (at least 1 hour before) prior to the test (Appendix 2). Ambient NO and temperature were also recorded (Appendix 6). Since spirometry may impact on FeNO, the test was performed before spirometry during the work shift.

A measurement for FeNO >50 ppb in adults in the absence of a recent upper respiratory tract infection suggested the presence of underlying airway inflammation as is commonly observed in allergic asthma (19, 20).

3.5 DATA MANAGEMENT AND ANALYSIS

3.5.1 Data management

Questionnaires were coded and then subjected to double entry with the assistance of the Centre of Medical Examinations in Maputo. All questionnaires were stored in confidential files until the completion of the study after which they will be destroyed. Each individual was assigned a unique 3-digit code. All data collection instruments, as well as all biological specimen containers, reflect this 3-digit code. Independent checks of range, validity, consistency and missing data were performed. Logic check programs were run to ensure that each value found in the data fell within the expected range or corresponded to possible values in the codebook and discrepancies were resolved.

3.5.2 Definition of variables

Key associations of interest involved investigating relationships between exposure explanatory variables (e.g. employment duration, job, exposure status), covariates (e.g. age, gender, smoking, atopy) and health outcomes (respiratory symptoms, immunological status, pulmonary function, fractional exhaled nitric oxide levels).

Table 3.4 summarizes the major variables of interest for the study (outcome variables, explanatory factors and covariates) that were investigated during the study.

Table 3.4: Outcome variables, exposure explanatory factors and covariates examined in the study

Type of variable	Binary Outcome	Continuous Outcome
Outcome variables	Asthma phenotypes (as defined in Table 3.5): Current asthma (atopic asthma and non-atopic asthma) Work-related asthma Bronchial reversibility Presence of airway inflammation Work-related rhinitis	FEV_1% predicted FEV_1 FeNO
Explanatory variables	Job type High risk work practices (machine sawing, sanding, drilling, planing, cleaning)	Years worked in each exposed group Inhalable wood dust particulate mass concentration in current job Inhalable β-glucans concentration in current job Inhalable endotoxin concentration in current job
Covariates	Gender Smoking status (current, ex-smoker, never smoker) Atopy (positive Phadiatop)	Age

For asthma, the key outcome variables of interest included:

- An asthma symptom score was computed based on the sum of answers (0=no, 1=yes) to five questions on asthma-like symptoms in the past 12 months (short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath), as has been described previously (14, 15). A binary variable was created from these five asthma-like symptoms (≥ 2 symptoms vs 0-1 symptom). Having ≥ 2 asthma-like symptoms was considered 'more symptomatic' and 0-1 asthma-like symptom 'less symptomatic'.

- Presence of airway inflammation as measured by elevated exhaled nitric oxide ≥ 50ppb, as a marker of allergic airway inflammation.

- Bronchial reversibility as measured by:
  - an absolute increase in FEV_1 ≥ 12% and ≥ 200 ml postbronchodilator, or
  - post-bronchodilator change in FEV_1% ≥9% of the predicted FEV_1

Asthma phenotypes, were defined in the categories as outlined in Table 5 (21).

Table 3.5: Categorization of asthma phenotypes

<table>
<tr><th colspan="2">Category</th><th>Definition</th></tr>
<tr><td rowspan="2">Current asthma</td><td>Atopic asthma</td><td>Having an asthma attack in the past 12 months, current use of asthma medication or woken up by an attack of shortness of breath in the past 12 months; and presence of atopy.</td></tr>
<tr><td>Non-atopic asthma</td><td>Having an asthma attack in the past 12 months, current use of asthma medication or woken up by an attack of shortness of breath in the past 12 months; and being non-atopic.</td></tr>
<tr><td>Work-related asthma</td><td colspan="2">Having an asthma attack in the past 12 months, current use of asthma medication or woken up by an attack of shortness of breath in the past 12 months; and work-related chest symptoms in the past 12 months that gets better when away from work or worsen on return to work.</td></tr>
</table>

3.5.3 Quality control of measurements

To maximize precision/reliability and accuracy of measurements, a standardized questionnaire (ECRHS questionnaire) was used, interviewers trained, and for continuous variables such as value of spirometry and FeNO measurements were repeated. For spirometry the highest values were used, whilst the mean was used for FeNO. All instruments that were used during the study were calibrated and piloted prior to use.

3.5.4 Statistical analysis

All statistical analyses were performed using STATA version 12 computer software (StataCorp, College Station, Texas, USA). Univariate, bivariate and multivariate analyses were performed for relevant outcome variables. Univariate analyses summarized the distribution of each measured variable. Exploratory bivariate analyses were used to assess the nature of the associations between outcomes, exposure and covariates. Regression models were developed to assess the exposure effects on the health outcomes. Multiple linear regression for continuous variables and logistic regression for categorical variables were performed. While stepwise modelling was used for the exposure models, saturated models were developed for the environmental risk factor analysis as well as the exposure response relationships to enable comparability between models within this study and externally with other studies.

a) Exposure assessment analysis

Descriptive univariate statistics were generated for the total sample distribution. Generalised linear models (GLM) regression models were developed to describe the determinants of variability of the various exposure variables. Since the data showed a lognormal distribution, the natural logarithm (ln) of the measured exposure was used as the dependent variable. A compound symmetry structure of the correlation matrix was assumed in that any two repeated measurements of the same worker had a similar correlation irrespective of the time interval between them. In light of this assumption, generalised estimation equation models (GEE) were computed to further evaluate the association between exposure variables and covariates taking into account repeated sample measurements on workers. Stepwise model building procedure was used to develop predictive models for inhalable dust particulate, endotoxin and β-glucan concentrations using only those covariates that were significant at the 10% level. Independent variables considered for entry ($p<0.1$) in the model included EG, job title, species of wood, building design, building size, local exhaust ventilation and wood dust cleaning methods. The model building process involved systematically adding significant covariates based on the GLM analysis and evaluating model improvement (increase in explained variance) using the difference in -2-log likelihood ratio between the two models. If no additional variability was explained by adding more variables, expansion of the model was stopped.

b) Health outcomes – asthma phenotypes analysis

In this study, both continuous and categorical analyses were conducted. Frequencies and percentages were used to summarize categorical variables, whilst the mean and standard deviation (and where appropriate median and interquartile range) was used for numerical variables. Unadjusted linear and logistic regression was used to investigate the association between continuous indices of bronchial reversibility (BDR – bronchodilator response) and airway inflammation (FeNO).

c) Host and environmental risk factor for asthma outcomes analysis

Continuous indices of FeNO were log transformed (natural log) before linear regression analysis was conducted and the results reported as geometric mean ratios and confidence intervals. Unadjusted logistic and linear and logistic regression analysis was conducted to explore the association between adverse health outcomes (e.g. asthma symptom score, work-related ocular nasal symptoms, work-related asthma symptoms, fixed airway obstruction, bronchial reversibility, FeNO≥ 50 ppb) and host-related attributes (e.g. age, gender, BMI, atopy,childhood-onset asthma, adult-onset asthma, repeated childhood chest infections).

Furthermore, unadjusted linear and logistic regression models were also developed to assess the relationship between relevant adverse health outcomes and self-reported occupational exposures (e.g. employment duration in factory, wood processing exposure categories, type of woods processed, chemicals used, cleaning activities). Multivariate linear and logistic regression models were adjusted for age, gender and smoking since these variables appeared to be the most consistent significant potential confounders identified in the univariate models. The results of these regression models are expressed as odds ratios and confidence intervals.

d) Exposure-response analysis

Operational definitions of exposure variables

Exposure levels were assigned to all workers based on environmental exposure assessment for wood dust particulate concentrations obtained for each job during the exposure assessment sampling. Both continuous and categorical current exposure metrics were used.

Current wood dust particulate exposures were defined based two exposure parameters:

- *current exposure category based on current job titles:* maintenance and upholsterer were regarded as the low exposure category; machine operators, painter-varnishers and assemblers were classified in the medium exposure category; and planers, sanders, sawyers and carvers in the high exposure category.

- *current exposure category based on tertile inhalable dust levels*: exposure was categorized as low exposure category (<4.68 mg/m^3), medium exposure category (4.68-4.71 mg/m^3) and high exposure category (>4.71 mg/m^3).

Cumulative wood dust particulate exposures were defined based two exposure parameters:

- *cumulative dust exposure based on current job* in the factory: was calculated as average inhalable dust concentration for the current job x employment duration in factory.

- *cumulative dust exposure based on all jobs in the factory:* was calculated as sum total of the (average inhalable dust particulate concentration for each job x employment duration for each job) across all jobs within the factory.

Categorical exposure metrics for cumulative exposure used quartiles, with the lowest quartile as the reference category.

Operational definitions of outcomes variables

An ***asthma symptom score*** was computed based on the sum of answers (0=no, 1=yes) to five questions reported in the past 12 months. These included the presence of shortness of breath while wheezing; being woken up with chest tightness; an attack of shortness of breath at rest; an attack of shortness of breath after exercise; and being woken up by an attack of shortness of breath. A binary variable was created from these five asthma-related symptoms (≥ 2 symptoms vs 0-1 symptom). Having ≥ 2 asthma-related symptoms was considered 'more symptomatic' and 0-1 symptom as 'less symptomatic' (11, 22).

Work-related asthma symptoms **and** ***work-related ocular–nasal symptoms*** were defined as symptoms (chest/ocular-nasal) experienced at any time during their work. A more specific variable for both these outcomes was defined as symptoms (either chest/ocular-nasal) experienced at work that improved when away from work.

The presence of ***atopy*** was defined as sensitization to common aeroallergens (house dust mites, grass pollens, cat, dog, and cockroach) as determined by a positive Phadiatop® test (Phadia AB, Uppsala, Sweden), classified as any value ≥0.35ku/L.

Both ***baseline obstruction*** **(FEV_1 /FVC < 70%)** as well as ***fixed airway obstruction*** defined as FEV_1 /FVC < 70% without improvement after bronchodilator administration was used, while ***bronchial reversibility*** was measured in two ways: i) as ≥12% and ≥200 ml FEV_1 increase post-bronchodilator and as ii) ≥9% FEV_1 increase post-bronchodilator as a proportion of FEV_1 % predicted.

Fractional exhaled nitric oxide (FeNO) results were interpreted as being i) low for values < 25ppb; ii) elevated for values 25 - 50ppb; and iii) high for values > 50ppb. A FeNO level > 50 ppb in the absence of a recent upper respiratory tract infection is generally considered to indicate the presence of eosinophilic airway inflammation associated with allergic asthma (19, 20).

3.6 HUMAN SUBJECT AND ETHICS

Ethics

Ethics approval was obtained from the Human Research Ethics Committee (HREC) of the University of Cape Town (HREC Ref: 543/2016), National Bioethics Committee of Ministry of Health of Mozambique (40/CNBS/2015) and University of Michigan Medical School Institutional Review Board (HUM00070862).

Consent

Informed written consent (Appendix 1) was sought prior to any tests being performed on any of the workers. All testing were done on a voluntary basis during working time at no direct cost to the worker.

Confidentiality of results and follow up

All individuals were given a written copy of their own results with interpretation. Individual results are confidential and personal information was only released with the worker's consent when the need arose. All workers with abnormal results were offered referral to Pulmonologist of Central Hospital of Maputo or Beira for further evaluation. Where the disease was not considered to be work-related, they were referred to general practitioner at Health Centre for further evaluation and /or treatment. Prior to the commencement of the study, the employer undertook not to discriminate against workers identified as having asthma. **Reporting and publication of results**

Oral briefings for the workforce were conducted to introduce the study and provide feedback of the results. Progress reports and a draft final report, will be provided to the factory management and the representatives of workers in order to investigate appropriate measures to address the shortcomings.

3.7 REFERENCES

1. Beaglehole B & Bonita R. Basic epidemology. 1993. 182 p.

2. Kespohl S., Sander I., Schulze J., Poppe M., Brüning T., Raulf-Heimsoth M. Development of an obeche wood allergen quantification assay for the assessment of allergen exposure in workplaces. Scand J Work Environ Heal. 2008;34(5):387–95.

3. Ronald LA, Davies HW, Bartlett KH, Kennedy SM, Teschke K, Spithoven J, et al. β (1 -3)-glucan exposure levels among workers in four British Columbia sawmills. Ann Agric Env Med. 2003;10:21–9.

4. Chamba P, Nunes E. Work-related asthma among workers in the wood-processing industry: A review. Current Allergy and Clinical Immunology. 2016;29 (2):110–7.

5. Smit J, Asnong W. The assessment of exposure Vinyl chloride and 1 , 2-Dichloroethane. ECVM. 2009;44.

6. Kenny LC, Aitken R, Chalmers C, Fabriès JF, Gonzalez-Fernandez E, Kromhout H, et al. A collaborative European study of personal inhalable aerosol sampler performance. Ann Occup Hyg. 1997;41(2):135–53.

7. Spaan S, Doekes G, Heederik D, Thorne PS, Wouters IM. Effect of extraction and assay media on analysis of airborne endotoxin. Appl Environ Microbiol. 2008;74(12):3804–11.

8. Rylander R CM. Airways inflammation among workers in poultry houses. Int Arch Occup Environ Health. 2006;79(6):487–90.

9. Burney PGJ, Luczynska C, Chinn S, Jarvis D. The European Community Respiratory Health Survey. Eur Respir J. 1994;7(5):954–60.

10. Janson C, Anto J, Burney P, Chinn S, De Marco R, Heinrich J, et al. The European community respiratory health survey: What are the main results so far? Eur Respir J. 2001;18(3):598–611.

11. Pekkanen J, Sunyer J, Anto JM, Burney P. Operational definitions of asthma in studies on its aetiology. Eur Respir J. 2005;26(1):28–35.

12. Le Moual N, Varraso R, Siroux V, Dumas O, Nadif R, Pin I, et al. Domestic use of cleaning sprays and asthma activity in females. Eur Respir J. 2012;40(6):1381–9.

13. Miller MR, Crapo R, Hankinson J, Brusasco V, Burgos F, Casaburi R, et al. General considerations for lung function testing. Eur Respir J. 2005;26(1):153–61.

14. Graham BL, Steenbruggen I, Barjaktarevic IZ, Cooper BG, Hall GL, Hallstrand TS, et al. Standardization of spirometry 2019 update an official American Thoracic Society and European Respiratory Society technical statement. American Journal of Respiratory and Critical Care Medicine. 2019;200 (8):E70–88.

15. Quanjer PH, Stanojevic S, Cole TJ, Baur X, Hall GL, Culver BH, et al. Multi-ethnic reference values for spirometry for the 3-95-yr age range: The global lung function 2012 equations. Eur Respir J. 2012;40(6):1324–43.

16. American Thoracic Society. Medical Section of the American Lung Association Lung Function Testing : Selection of Reference Values and. Am Rev Respir Dis. 1991;144(5):1202–18.

17. Tuomisto LE, Ilmarinen P, Lehtimäki L, Tommola M, Kankaanranta H. Immediate bronchodilator response in FEV 1 as a diagnostic criterion for adult asthma. Eur Respir J. 2019;53(2):1–7.

18. ATS and ERS. ATS/ERS recommendations for standardized procedures for the online and offline measurement of exhaled lower respiratory nitric oxide and nasal nitric oxide, 2005. Am J Respir Crit Care Med. 2005;171(8):912–30.

19. Bjermer L, Alving K, Diamant Z, Magnussen H, Pavord I, Piacentini G, et al. Current evidence and future research needs for FeNO measurement in respiratory diseases. Respir Med. 2014;108(6):830–41.

20. Dweik RA, Boggs PB, Erzurum SC, Irvin CG, Leigh MW, Lundberg JO, et al. An Official ATS Clinical Practice Guideline: Interpretation of Exhaled Nitric Oxide Levels (FE NO) for Clinical Applications. Am J Respir Crit Care Med. 2011;184:602–15.

21. Baatjies R, Lopata a L, Sander I, Raulf-Heimsoth M, Bateman ED, Meijster T, et al. Determinants of asthma phenotypes in supermarket bakery workers. Eur Respir J. 2009;34(4):825–33.

22. Sunyer J, Pekkanen J, Svanes C, Janson C, Marco R De, Burney P. Asthma score : predictive ability and risk factors. Allergy. 2007;62:142–8.

CHAPTER 4

Characterisation of exposure to wood dust particulate, endotoxins and glucans and their determinants among workers in the Mozambique wood processing industry

ABSTRACT

Background: Various exposure assessment studies have reported that workers in the wood processing industry are exposed to variable concentrations of hazardous agents (microorganisms, endotoxins, glucans and terpenes) associated with wood dust. Previous exposure characterisation studies have demonstrated wide ranges of wood dust particulate (0.05–12.0 mg/m^3), microorganisms (1.696–2,000 cfu/m^3 × 10^3), endotoxins (0.4–6.93 ng/m^3), glucans (3.5–18.9 ng/m^3) and terpenes (0.23–158 mg m^3). It has been suggested that various factors including weather conditions, tree species, wood condition, jobs, tasks, use of certain types of equipment, control measures, poor maintenance of equipment and ventilation systems are responsible for this variation in the wood processing industry. The main objective of this study was to characterize the exposure to wood dust particulate, endotoxins and glucans and their determinants among workers in the Mozambique wood processing industry.

Methods: A cross-sectional study of 21 furniture/joinery companies located in 3 provinces of Mozambique was conducted during the period 2016 - 2019. Both qualitative and quantitative methods of exposure assessment were utilized to define exposure profiles and similarly exposed groups (SEGs). The qualitative exposure assessment entailed a walk-through inspection that classified jobs with high, medium or low exposures. The quantitative exposure assessment component defined SEGs according to exposure metrics for wood dust particulate, glucan and endotoxin concentrations. A random sample of 30 workers from different factory workplaces participated in the personal environmental sampling of wood dust measurements. A total of 124 inhalable dust samples were collected over a range of job titles that included planers, sawyers, drillers, machine repairers, sanders, painters and upholsterers. The samples were analyzed for inhalable dust particulate, endotoxins and (1-3)-β-D-glucans concentrations. During the sampling survey, information on potential exposure determinants such as exposure group, job title, wood species, handling dry or fresh wood, building characteristics, local exhaust ventilation, sharpening of cutting tools, and cleaning procedures, were collected.Following correlational and bivariate analysis, generalized linear modelling and generalized estimation equations were conducted to investigate the significant determinants of inhalable dust particulate, endotoxins and (1-3)-β-D-glucans levels.

Results: The mean (GM) inhalable wood dust concentrations were 3.29 mg/m^3 for dust particulate (GSD= 3.04), 98 endotoxin units (EU)/m^3) (GSD=5.05) and 123 ng/m^3 for (1-3)-β-D-glucans (GSD= 5.05). A modest correlation was observed between log-transformed inhalable dust and endotoxin (Pearson r = 0.48, p <0.001) and with (1-3)-β-D-glucans concentrations

(Pearson r = 0.40 $p < 0.001$). However, there was a very poor correlation between endotoxins and (1-3)-β-D-glucans. In the multivariate regression models, SEGs such as sawing (GM ratio=4.18), painting (GM ratio=4.01), carpentry (GM ratio=3.74) and machinery (GM ratio=2.39), and certain wood species such as Mahogany bean (GM ratio=3.39) and African sandalwood (GM ratio=3.19) were significant predictors of higher dust particulate levels. Whilst, working with Panga-panga (GM ratio=0.36) and African teak (GM ratio=0.39) species as well as cleaning using damp rags were associated with lower inhalable dust levels. Significant determinants of endotoxin exposures included African sandalwood (GM ratio=9.21), working in closed buildings (GM ratio=2.10) and sawing (GM ratio=1.48). On the other hand, using dry wood (GM ratio=0.06), SEGs performing joinery work (GM ratio=0.14) and painting (GM ratio=0.32), cleaning using damp rags (GM ratio=0.35) and Panga-panga wood species (0.54) were associated with lower endotoxin levels. Semi-closed buildings (GM ratio=2.14) were the main determinants of elevated inhalable (1-3)-β-D-glucan levels. Using damp rags for cleaning (GM ratio=0.53) was also associated with lower inhalable (1-3)-β-D-glucan levels.

Conclusion: Workers in the Mozambique wood processing industry are exposed to relatively high levels of wood dust particulate exposures that are above international exposure standards. African sandalwood and mahogany bean wood dust species and poorly designed buildings were associated with higher inhalable wood dust particulate exposures, whereas other wood species such as Panga-panga and African teak wood, as well as good work practices involving the regular sharpening of cutting tools and use of damp cleaning methods were associated with lower wood dust levels.

4.1 INTRODUCTION

Wood dust production occurs when machines or tools utilised in wood processing generate unwanted byproducts during the production process. Airborne wood dust is one of the most common occupational hazards in the wood industry (1). Dust generated from wood processing is a heterogeneous mixture of inorganic and organic particles comprising wood fragments, microorganisms, endotoxins, mycotoxins and allergens, as well as other low molecular weight chemical compounds that have the potential to cause adverse respiratory health effects upon inhalation(2). These adverse respiratory health effects can affect both the upper and lower airways. Health effects affecting the upper airways include rhinitis and nasopharyngeal carcinoma, while wood dust affecting the lower airways result in allergic alveolitis, occupational asthma and chronic lung function deficits (3).

Various exposure assessment studies have reported that workers in the wood processing industry are exposed to variable concentrations of hazardous agents (microorganisms, endotoxins, glucans and terpenes) associated with wood dust. The exposure estimates had wide ranges for wood dust particulate (0.05 - 12.0 mg/m^3, microorganisms (1.696 - 2000 cfu/m^3 x10^3), endotoxins (0.4 - 6.93 ng/m^3), (1-3)-β-D-glucans (3.5 - 18.9 ng/m^3) and terpenes (0.23 - 158 mg m^3) (4).

In studying the determinants of exposures in wood workers, Teschke et al. (5) initially suggested that weather conditions, tree species, wood condition, jobs, tasks and use of certain types of equipment control measures were among the potential determinants of exposure to inhalable wood dust particulate, resin acids, and monoterpenes in a lumber mill environment. Furthermore, Ronald et al.(6) found that weather conditions, log storage methods (land-storage or water-storage), wood condition (dry or green), tree species, production level, jobs and tasks were potential determinants of exposure to β (1-3)- glucans in sawmills. In the Danish furniture industry Schlünssen et al. (7) reported that sanding of wood, use of fully-automatic machines, manual work, cleaning of work pieces with compressed air, kitchen producing factories and small workplaces (<20 employees) were associated with increased wood dust levels. On the other hand, manual assembling or packing, sanding with adequate exhaust ventilation, vacuum cleaning of machines and the use of special cleaning staff were associated with decreased dust levels. Furthermore, Douwes' et al. (8) demonstrated that the use of hand tools and conventional cleaning methods (dry wiping and sweeping) significantly contributed to high dust exposures in joineries and furniture manufacturing in New Zealand, whilst the use of vacuum extraction on hand tools and alternative cleaning methods were associated with significantly reduced wood dust exposures.

There are few studies that have conducted comprehensive assessment of wood dust particulates and associated exposures using different exposure variables and the factors that contribute towards such exposures, especially in African settings. Furthermore, there have not been any studies that have assessed the role of exotic wood species used in the Mozambique wood processing industry and how factors such as building design (open, semi-open and closed), building size, use of ventilation and cutting tools, and work practices, influence wood dust exposures.

The main objective of this study was to characterize exposure to inhalable wood dust particulate, endotoxins and (1-3)-β-D-glucans and their determinants among workers in the Mozambique wood processing industry.

4.2 METHODS

4.2.1 THE PRODUCTION PROCESS

In general, wood processing in Mozambique comprises various steps as outlined in Figure 2.5 (chapter 2). Prior to processing the *front-end process* involves procuring wood at the forestry concession where it is cut into different sizes of blocks and slabs or purchased at the wood market. The fresh wood is then seasoned or subjected to sun exposure in a courtyard or greenhouse. After seasoning the wood undergoes treatment with chromated copper arsenate (CCA). Prior to the commencement of *processing of the wood* and manufacturing of the furniture product a desired design is selected. The seasoned wood blocks are cut into the desired shape and sliced according to the design requirements. Thereafter, the slices of wood are molded into the desired shape according to the design. Carving entails applying different patterns made in the wood. Once the different pieces are carved and molded, these parts/pieces are assembled or fixed together to give shape to the final product. The assembled product is sanded to make the surface smooth, where after finishing material is applied to prepare the surface ready for paint or polish. The furniture is then upholstered according specifications of design. The *back-end*process also involves workers employed in cleaning workshops, locksmith, maintenance services, office, forestry management and wood machine repair.

4.2.2 WALK-THROUGH SURVEY

A walk-through inspection was conducted in each factory to assess the work processes and to obtain more detailed information with regard to province, factory, job titles, work tasks, wood species used, state of woods processed, building characteristics and specific control measures implemented to reduce wood dust exposures in each factory. The checklist also included questions on building design (open, semi-closed, closed), presence and type of ventilation system, wood dust cleaning methods (wet or dry), frequency of cleaning, waste disposal and whether workers had received education and training. The checklist used in this study was adapted from previous studies on bakery workers conducted by the collaborating study team (Appendices 7 and 8). The inspections were conducted during working time by a team that included an occupational hygienist and occupational medicine physician. During the walk-through inspection, each member of the team conducted their own independent evaluation and interviews with factory managers and worker representatives. The individual findings of each team member were discussed, and consensus reached about the final recording on the checklist.

Based on the information in Table 4.1, most factory workplaces (n=17; 77%) processed both dry and fresh woods, while only four (18%) companies processed dry wood and one (5%) exclusively handled fresh wood.

Generally, workers using drilling, planing and sanding machines appeared to have visibly very high wood dust exposures, compared to workers using sawing or carving machines and those in cleaning workshops. Workers involved in machine repairing, upholstering, manual sawing and setting had visibly reduced wood dust exposures. These observations were used to categorise workers into similar EGs (SEGs).

Table 4.1: Geographical information of workplaces, number of workers employed, species and physical state of woods processed in the Mozambiquan wood processing industry

Province	Location	Factory	No. of workers	Wood species processed*	Physical state of wood	
					Dry	Fresh
Maputo	Matola	SECAMA	21	MB	Yes	Yes
Maputo	Matola	Yola	23	MB, AT, P	Yes	Yes
Maputo	Matola	Luxoflex	46	MB, AT,PP	Yes	Yes
Maputo City	Maputo	SB	11	MB, AT,PP,LIW,P	Yes	Yes
Maputo City	Maputo	FERSOL	24	MB, AT, PP, LIW, AM, AS, P	Yes	Yes
Maputo City	Maputo	Simbine	8	MB, AT, PP, LIW, AM, AS, P	Yes	Yes
Maputo City	Maputo	Manguele	18	MB, AT, PP, LIW, AM, AS, P	Yes	Yes
Maputo City	Maputo	Nwavele	10	MB, AT, PP, LIW, P	Yes	Yes
Maputo City	Maputo	ERFI	11	MB, AT, PP, LIW, P	Yes	Yes
Maputo City	Maputo	Langa	11	MB, AT, PP, LIW, P	Yes	Yes
Maputo City	Maputo	Marrengule	13	MB, AT, PP, LIW, AM, P	Yes	No
Maputo City	Maputo	Repinga	7	MB, AT, PP, LIW, AM, AS, P	Yes	Yes
Maputo City	Maputo	Muda Carp	7	MB, AT, PP, LIW, P	Yes	No
Maputo City	Maputo	Comiche	18	MB, AT, PP, AM, P	Yes	No
Maputo City	Maputo	Machanguane	5	MB, AT, PP, P	Yes	Yes
Sofala	Beira	IMM Wood Process	30	MB, AT, PP, ZW	Yes	Yes
Sofala	Cheringoma	IMM Florestal Concession	22	MB, AT, PP,MT,ZW	No	Yes
Sofala	Beira	Mutende	30	MB, AT, PP,MT	Yes	Yes
Sofala	Beira	Movarte	34	MB, AT, PP,MT,ZW	Yes	No
Sofala	Beira	Fim da Vida	19	MB, AT, PP, P, MS	Yes	Yes
Sofala	Cheringoma	Levasflor	121	MB, AT, PP, LIW, AM, MT,MS, MSS	Yes	Yes
Sofala	Beira	MPM	24	MB, AT, PP, LIW, AS, P, MT,MS, MSS	Yes	Yes

* Wood species processed: MB *(Mahogany bean*); AT (*African Teak*); PP (*Panga-panga);* LIW (*Lebombo Iron Wood*); AM (*African Mahogany*); AS (*African sandalwood*); MT (*Mutondo*); ZW (*Zebrawood*); MS (*Missanda*); MSS (*Messassa*); P (*Pine*)

4.2.3 MEASUREMENT OF AIRBORNE WOOD DUST PARTICULATE, ENDOTOXINS AND GLUCANS

An environmental exposure assessment study of workers currently employed in the wood processing factories was conducted.

a) Study population

The study population comprised workers from nine wood processing factories within three provinces of Mozambique. The factories had an average of 43 employees (range: 11 – 121) currently working on site. The factories were randomly selected based on location, size and building design. Within each factory, workers in seven job titles could be distinguished viz. planer, sawyer, driller, machine repairer, sander, painter and upholsterer. Workers performing similar jobs were grouped into six similar exposure groups (SEGs).

Personal environmental sampling was performed on selected study subjects during five consecutive days (from Monday to Friday). Environmental samples were collected from the same worker during the work shift.

A random sample of 30 workers from six SEGs (similar exposure group) and seven job titles finally participated in the environmental dust measurement sampling. A total of 124 environmental samples were collected.

b) Personal wood dust sampling measurements

Full-shift inhalable dust samples were collected on each participating worker using a PAS6 sampling head (9) placed in the breathing zone and connected to a Gillian Gil Air pump with constant-flow calibrated at 2 litres per minute. The volume of air sampled was calculated based on the flow rate and duration of sampling. Teflon filters (Millipore; pore size 1.0 µm, 25 mm diameter) mounted in the sampling head were used to collect the wood dust. Filters were weighed before and after sampling using a microbalance (Mettler Toledo AG245) with 0.01 mg readability. Filters were acclimatized prior to weighing for 24 hours in a room with constant relative humidity (35%), temperature (22.6°C) and air pressure 1019mbar to ensure standard weighing conditions. Sampling heads containing filters were kept in sterile plastic bags to avoid contamination. Dust samples were stored at -20° C with moisture absorbent paper immediately after collection until further processing. In addition, one field blank was collected per each shift per day to control for cross contamination. Workers were observed throughout the shift and detailed information on tasks performed and specific work practices followed were recorded during personal environmental sampling.The limit of detection (LOD) for the dust was 0.08 mg, calculated using the average weight difference of the blank filters plus three times the standard deviation. None of the samples collected had values below the LOD for total dust particulate. The results of dust measurements were recorded on the environmental data collection sheet (Appendix 9).

The exposure assessment was overseen by Prof. Antonio Cumbane of Department of Chemical Engineering of Eduardo Mondlane University while the laboratory analysis of samples for endotoxins and glucans was conducted by Dr. Tanusha Singh at the National Institute for Occupational Health (NIOH) in South Africa.

c) Analysis of samples for endotoxins and glucans.

Endotoxins

For extraction and analysis of endotoxins filters were immersed in 5 ml of pyrogen- free water plus Tween 20 (0.05% v/v). After shaking for 60 min on a horizontal shaker, the tubes were centrifuged for 15 min at 1000 g (2094 rpm). Supernatants were harvested and stored in 0.1 ml aliquots at -20^{o}C until analysis. The endotoxins concentration was determined in supernatant using an endpoint chromogenic Limulus amebocyte lysate (LAL) method Lonza, Walkersville, USA. For each assay, a standard curve of an Escherichia coli standard obtained by the supplier was created in the concentration range 0.1– 1.0 EU ml^{-1} (10 EU = 1.0 ng) (10). The results were estimated as endotoxins units per cubic meter (EU m^{-3}).

(1-3)-β-D-Glucans

Following extraction for endotoxins, the aliquot was diluted two-fold with pyrogen free water with 0.05% Tween 20 and heat treated by autoclaving at 120°C for 1 hour before (1-3)-β-D-glucans determination. The (1-3)-ß-D-glucans was assayed using the Glucatell assay (Associates of Cape Cod, East Falmouth, MA, USA). The detection limit for (1-3) β-D-glucans was 20 pg/ml (11). All dust samples were analyzed in duplicate. The (1-3)-β-D-glucans levels were expressed as ng m^{-3}.

4.2.4 STATISTICAL ANALYSIS

Statistical analyses

All statistical analyses were performed using STATA version 12 computer software (StataCorp, College Station, Texas, USA). Descriptive statistics were calculated stratified by exposure group and job title. The exposure data followed a skewed distribution, requiring the data to be log transformed prior to statistical analysis. Job titles were grouped into similar exposed groups (SEG's), based on their tasks and associated exposures. Each EG consisted of one or more job titles that were considered to best represent similar tasks and exposures. This was based on information obtained from the walk-through inspection checklist and an understanding of the wood processing steps within each factory (Figure 2.1).

Descriptive univariate statistics were generated for the total sample distribution. Generalised linear models (GLM) regression models were developed to describe the determinants of variability of the various exposure variables. Since the data showed a lognormal distribution, the natural logarithm (ln) of the measured exposure was used as the dependent variable. A compound symmetry structure of the correlation matrix was assumed in that any two repeated measurements of the same worker had a similar correlation irrespective of the time interval between them. In light of this assumption, generalised estimation equation models (GEE) were computed to further evaluate the association between exposure variables and covariates taking into account repeated sample measurements on workers. Stepwise model building procedure was used to develop predictive models for inhalable dust particulate, endotoxin and β-glucan concentrations using only those covariates that were significant at the 10% level. Independent variables considered for entry ($p<0.1$) in the model included EG, job title, species of wood, building design, building size, local exhaust ventilation and wood dust cleaning methods. The approach used for including wood species in the model was to assign one (1) if the wood species was used and zero (0) if it was not used. All species were included in the multivariate model. The model building process involved systematically adding significant covariates based on the GLM analysis and evaluating model improvement (increase in explained variance) using the difference in -2-log likelihood ratio between the two models. If no additional variability was explained by adding more variables, expansion of the model was stopped.

4.3 RESULTS

4.3.1 Personal exposure levels

A total of 124 full-shift personal samples were collected from 30 workers, with a geometric mean exposure of 3.29 mg/m^3 with a very wide range (0.33 – 119.36mg/m^3) (Table 4.2). The exposure levels based on exposure groups (EGs) were very similar to respective job titles in that EG since most EGs comprised only one job title. Workers in the painting (GM = 4.30 mg/m^3) and machinery (GM = 4.10 mg/m^3) EGs had the highest mean inhalable dust particulate concentrations, followed by carpentry (GM = 3.84 mg/m^3) and sawing (GM = 3.53 mg/m^3) EGs that had very similar levels. Exposure, based on job titles revealed that painters (GM = 4.30 mg/m^3) and drillers (GM = 4.10 mg/m^3) had the highest dust particulate exposures followed by sanders and planers (GM = 3.81-3.88 mg/m^3). In this study machine repairers had the lowest mean inhalable dust particulate exposures.

Table 4.2: Personal inhalable dust particulate exposure stratified by exposure group and job title among wood processing workers in Mozambique

	Inhalable dust particulate (mg/m^3)					
	K	**N**	**AM**	**GM**	**GSD**	**Range**
Exposure group						
Sawing	9	36	6.99	3.53	2.73	0.67 – 94 .49
Machinery	2	10	4.71	4.10	1.66	2.36 – 13.02
Carpentry	13	53	10.38	3.84	3.65	0.33 – 119.36
Joinery	3	10	1.80	1.40	2.07	0.51 – 5.73
Painting	2	10	4.65	4.30	1.52	2.18 – 8.04
Maintenance	1	5	0.90	0.79	1.73	0.47 – 1.76
Job title						
Planer	5	21	10.84	3.88	3.64	0.33 – 118.70
Sawyer	9	36	6.99	3.53	2.73	0.67 – 94.49
Driller	2	10	4.71	4.10	1.66	2.36 – 13.02
Machine repairer	1	5	0.90	0.79	1.73	0.47 – 1.76
Sander	8	32	10.09	3.81	3.73	0.33 – 119.36
Painter	2	10	4.65	4.30	1.52	2.18 – 8.04
Upholster	3	10	1.80	1.40	2.07	0.51 – 5.73
Overall	**30**	**124**	**7.40**	**3.29**	**3.04**	**0.33 – 119.36**

K: number of workers sampled in an exposure group; n: number of measurements in group; AM: Arithmetic mean; GM: Geometric mean; GSD: Geometric standard deviation

4.3.2 Endotoxins exposure levels

In this study, none of the samples had endotoxin levels below the limit of detection (0.5 EU/m^3). The overall GM concentration of endotoxin exposures was 98 EU/m^3 (GSD = 5.05 EU/m^3) having a very wide range (3 – 37,868 EU/m^3) (Table 4.3).The highest endotoxin EGs were sawing (GM = 128 EU/m^3) and machinery (GM= 124 EU/m^3) followed by carpentry (GM= 104 EU/m^3). Highest exposures based on job titles, were observed in planers (GM = 173 EU/m^3), sawyers (GM = 128 EU/m^3) and drillers (GM= 124 EU/m^3). As with inhalable dust particulates, machine repairers had the lowest mean endotoxin exposures.

Table 4.3: Personal inhalable endotoxin exposure stratified by exposure group and job title among wood processing workers in Mozambique

	Inhalable endotoxin (EU/m^3)					
	K	**N**	**AM**	**GM**	**GSD**	**Range**
Exposure group						
Sawing	9	36	947	128	6.64	6 – 15306
Machinery	2	10	205	124	3.03	28 – 551
Carpentry	13	53	962	104	5.57	3 – 37868
Joinery	3	10	69	49	2.21	16 – 290
Painting	2	10	130	79	2.81	23 – 472
Maintenance	1	5	44	32	2.40	11 – 121
Job title						
Planer	5	21	2121	173	6.91	3 – 37868
Sawyer	9	36	947	128	6.64	6 – 15306
Driller	2	10	205	124	3.03	28 – 551
Machine repairer	1	5	44	32	2.40	11 – 121
Sander	8	32	202	74	4.48	3 – 1634
Painter	2	10	130	79	2.81	23 – 472
Upholster	3	10	69	49	2.21	16 – 290
Overall	**30**	**124**	**720**	**98**	**5.05**	**3 – 37868**

K: number of workers sampled in an exposure group; n: number of measurements in group; AM: Arithmetic mean; GM: Geometric mean; GSD: Geometric standard deviation

4.3.3 (1-3)-β-D-Glucans exposure levels

Table 4.4 shows that the geometric mean personal (1-3)-β-D-glucans exposure was 123 ng/m^3 (GSD = 5.05ng/m^3). The highest mean (1-3)-β-D-glucan exposures were found in joinery (GM =

170 ng/m^3) and maintenance (GM = 161 ng/m^3) EGs, followed by machinery and carpentry (GM= 129ng/m^3) and sawing (GM = 111 ng/m^3). With regard to job titles, upholsters (GM = 170 ng/m^3), machine repairers (GM= 161 ng/m^3) and sanders (GM = 152 ng/m^3) had the highest exposures, whilst relatively lower exposures were observed in painters (GM = 83 ng/m^3).

Table 4.4: Personal inhalable (1-3)-β-D-Glucans exposure stratified by exposure group and job title, among wood processing workers in Mozambique

	Inhalable (1-3)-β-D-Glucans (ng/m^3)					
	K	**N**	**AM**	**GM**	**GSD**	**Range**
Exposure group						
Sawing	9	36	191	111	2.88	10 – 1258
Machinery	2	10	168	129	2.06	49 – 572
Carpentry	13	53	247	129	4.34	0 – 1543
Joinery	3	10	346	170	3.24	51 – 1751
Painting	2	10	186	83	5.21	3 – 489
Maintenance	1	5	466	161	4.87	32 – 1843
Job title						
Planer	5	21	221	101	6.65	0 – 937
Sawyer	9	36	191	111	2.88	10 – 1258
Driller	2	10	168	129	2.06	49 – 572
Machine repairer	1	5	466	161	4.87	32 – 1843
Sander	8	32	264	152	3.04	18 – 1543
Painter	2	10	186	83	5.21	3 – 489
Upholster	3	10	346	170	3.24	51 – 175
Overall	**30**	**124**	**236**	**123**	**5.05**	**0 - 1842**

K: number of workers sampled in an exposure group; n: number of measurements in group; AM: Arithmetic mean; GM: Geometric mean; GSD: Geometric standard deviation

4.3.4 Correlation between exposure variables

A modest correlation was observed between log-transformed inhalable dust particulate concentration and log-transformed endotoxin concentrations (Pearson r = 0.48, p <0.001) as well as with β – glucan levels (Pearson r = 0.40 p< 0.001) and (Table 4.5) (Figures 4.2-4). However, there very was a very poor correlation between β – glucans and endotoxins.

Table 4.5: Correlation matrix for exposure metrics (log transformed, ln) among wood processing workers in Mozambique

Exposure variables	Inhalable dust particulate (ln)	(1-3)-β-D-Glucans (ln)
(1-3)-β-D-glucans (ln)	0.40**	-
Endotoxins (ln)	0.48**	0.17*

* p 0.06; ** p < 0.001

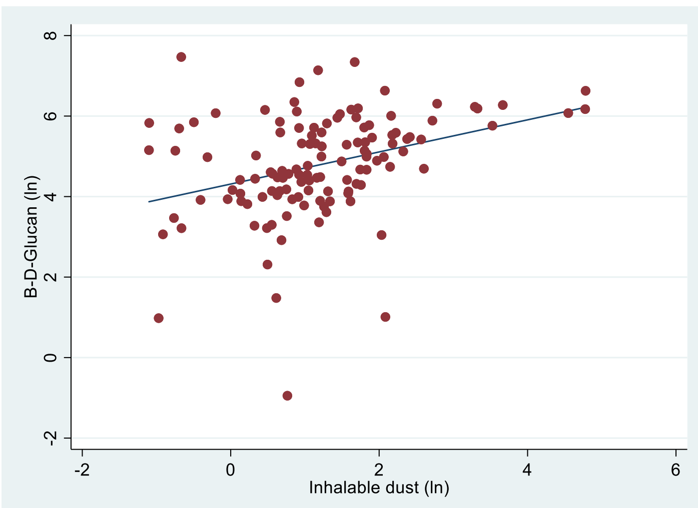


Figure 4.1: Relationship between inhalable dust particulate (mg/m^3) and (1-3)-β-D-Glucans (ng/m^3) concentration among wood processing workers in Mozambique

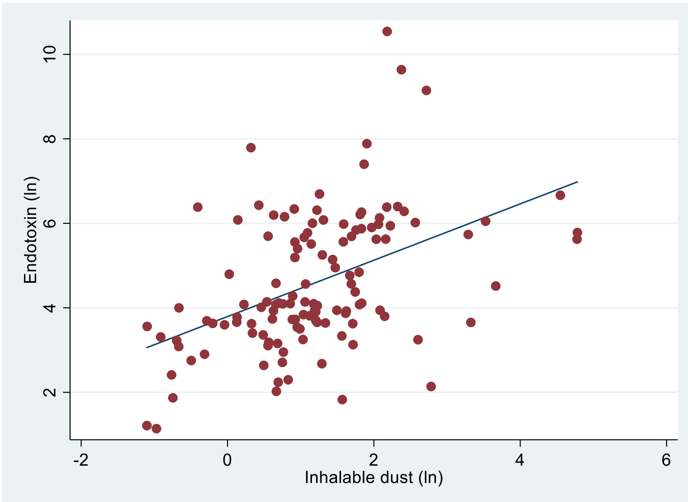


Figure 4.2: Relationship between inhalable dust particulate (mg/m^3) and endotoxin (EU/m^3) concentration among wood processing workers in Mozambique

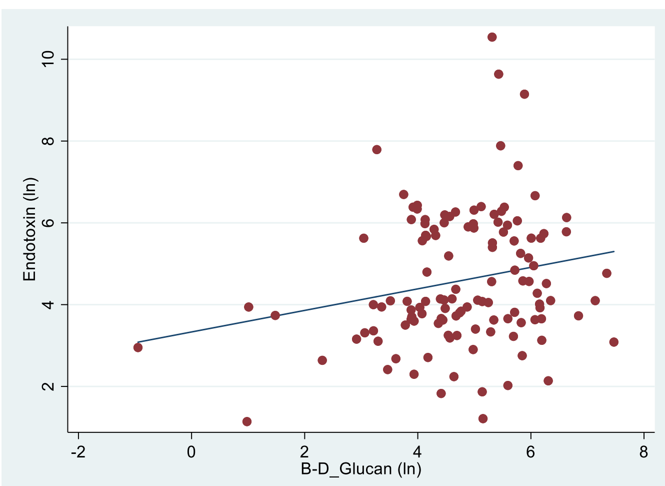


Figure 4.3: Relationship between inhalable (1-3)-β-D-Glucans (ng/m^3) and endotoxin (EU/m^3) concentration among wood processing workers in Mozambique.

4.3.5 Determinants of exposure variability

Bivariate linear regression analyses

In the bivariate linear regression analyses (Table 4.6) for inhalable dust particulate, both EG and job title explained the greatest variability in the log-transformed inhalable dust particulate levels (adjusted $r^2 = 0.13$, p=0.005), followed by factory (adjusted $r^2 = 0.11$, p=0.095). Overall, in addition to EG and job title, other factors such as wood species (mahogany bean wood, pine wood), building design and cleaning methods that used compressed air for machine maintenance were significant predictors of elevated dust exposures. On the other hand, predictors such as certain wood species (African teak and Panga Panga), larger building size, larger workforce size (≥ 25), sharpening cutting tools regularly and cleaning with damp rags were associated with lower dust levels.

With regard to endotoxins, factory (adjusted $r^2 = 0.19$, p=0.002) explained the greatest variability, followed by cleaning methods using damp rags (adjusted $r^2 = 0.11$, p=<0.001) (Table 4.6). Overall, predictors included factory, wood species (African teak wood, Lebombo ironwood, African sandalwood, pine wood) and closed building design were significant predictors of elevated exposures. On the other hand working with Panga-panga wood species, larger workforce size (≥ 25), training workers on dust control and cleaning activities using damp rags were associated with lower levels.

For (1-3)-β-D-glucans, the factory variable explained the greatest variability (adjusted $r^2 = 0.22$, p= <0.001), followed by building design (adjusted $r^2 = 0.11$, p=0.001) (Table 4.6). Overall, the results revealed that building design, fresh wood and Lebombo ironwood species were significant predictors of elevated glucans levels. Whilst, predictors such as factory and using damp rags for cleaning was associated with lower levels.

Table 4.6: Parameter estimates for inhalable particulate dust, endotoxin concentration among wood processing workers in Mozambique

Factor		Inhalable dust				Glucans				Endotoxin			
	N = 124 (%)	**β (SE)**	**GM Ratio**	**r^2**	**p-value**	**β (SE)**	**GM ratio**	**r^2**	**p-**	**β (SE)**	**GM ratio**	**r^2**	**p-value**
Province													
Maputo City	10 (8%)	0				0				0			
Maputo	55 (44%)	0.02 (0.38)	1.02	0.03	0.956	-0.10 (0.43)	0.90	0.08	0.809	-0.84 (0.54)	0.43	0.08	0.121
Sofala	59 (48)	-0.35 (0.38)	0.70	0.03	0.354	-0.80 (0.42)	0.45	0.08	0.062	-1.52 (0.54)	0.28	0.08	**0.005***
Factory													
SECAMA	15 (12%)	0											
Carpintaria SB	10 (8%)	-0.37 (0.44)	0.69	0.11	0.401	-0.49 (0.48)	0.61	0.22	0.311	1.69 (0.62)	5.42	0.19	**0.007***
Yola Mobilias	20 (16%)	-0.39 (0.37)	0.68	0.11	0.290	-1.27 (0.40)	0.28	0.22	**0.002***	1.09 (0.52)	2.97	0.19	**0.037***
Luxoflex	20 (16%)	-0.58 (0.37)	0.56	0.11	0.124	-0.35 (0.40)	0.70	0.22	0.379	1.26 (0.52)	3.53	0.19	**0.016***
Industria Madereira	11 (9%)	-0.76 (0.43)	0.47	0.11	0.082	-0.56 (0.46)	0.57	0.22	0.229	0.21 (0.60)	1.23	0.19	0.729
Mutende	10 (8%)	-0.50 (0.44)	0.61	0.11	0.259	-1.34 (0.48)	0.26	0.22	**0.006***	-0.10 (0.62)	0.90	0.19	0.867
Fim da Vida	8 (7%)	0.04 (0.48)	1.04	0.11	0.939	-0.90 (0.51)	0.41	0.22	0.082	1.59 (0.66)	4.90	0.19	**0.018***
LevasFlor	20 (16%)	-1.18 (0.37)	0.31	0.11	**0.002***	-1.50 (0.40)	0.22	0.22	**0.000***	-0.13 (0.52)	0.88	0.19	0.809
Movarte	10 (8%)	-0.62 (0.44)	0.54	0.11	0.167	-1.92 (0.48)	0.15	0.22	**0.000***	-0.14 (0.62)	0.87	0.19	0.818
Exposure group													
Maintenance	5 (4%)	0											
Sawing	36 (29%)	1.49 (0.51)	4.44	0.13	**0.004***	0.23 (0.68)	1.26	0.02	0.731	1.39 (0.77)	4.01	0.05	0.075
Machinery	10 (8%)	1.64 (0.58)	5.16	0.13	**0.005***	0.39 (0.76)	1.48	0.02	0.614	1.36 (0.89)	3.90	0.05	0.127
Carpentry	53 (43%)	1.58 (0.50)	4.85	0.13	**0.002***	0.39 (0.67)	1.48	0.02	0.560	1.18 (0.76)	3.25	0.05	0.121
Joinery	10 (8%)	0.57 (0.58)	1.77	0.13	0.332	0.67 (0.76)	1.95	0.02	0.385	0.42 (0.89)	1.52	0.05	0.637
Painting	10 (8%)	1.69 (0.58)	5.42	0.13	**0.004***	-0.05 (0.76)	0.95	0.02	0.945	0.90 (0.89)	2.46	0.05	0.309
Job title													
Machine repair	5 (4%)	0											
Planer	21 (17%)	1.59 (0.53)	4.90	0.13	**0.003***	0.14 (0.70)	1.15	0.03	0.838	1.69 (0.80)	5.42	0.07	**0.036***
Sawyer	36 (29%)	1.49 (0.51)	4.44	0.13	**0.004***	0.23 (0.68)	1.26	0.03	0.731	1.39 (0.76)	4.01	0.07	0.072
Driller	10 (8%)	1.64 (0.58)	5.16	0.13	**0.006***	0.39 (0.76)	1.48	0.03	0.614	1.36 (0.88)	3.90	0.07	0.123
Sander	32 (26%)	1.57 (0.51)	4.81	0.13	**0.003***	0.55 (0.68)	1.73	0.03	0.420	0.85 (0.77)	2.34	0.07	0.273
Painter	10 (8%)	1.69 (0.58)	5.42	0.13	**0.004***	-0.05 (0.76)	0.95	0.03	0.945	0.90 (0.88)	2.46	0.07	0.304
Upholsterer	10 (8%)	0.57 (0.58)	1.77	0.13	0.334	0.67 (0.76)	1.92	0.03	0.385	0.42 (0.88)	1.52	0.07	0.633
Wood species													
Mahogany bean	119 (96%)	0.93 (0.50)	2.53	0.03	0.066	-0.57 (0.58)	0.57	0.01	0.332	0.95 (0.74)	2.59	0.01	0.200
African teak	104 (84%)	-0.46 (0.27)	0.63	0.02	0.091	-0.36 (0.31)	0.70	0.01	0.245	0.75 (0.39)	2.12	0.03	0.056
Panga-panga	84 (68%)	-0.63 (0.21)	0.53	0.07	**0.003***	-0.22 (0.25)	0.80	0.01	0.377	-0.65 (0.31)	0.52	0.04	**0.036***
Lebombo ironwood	22 (18%)	0.33 (0.26)	1.39	0.01	0.202	0.53 (0.30)	1.70	0.03	0.078	0.85 (0.37)	2.34	0.04	**0.024***
African mahogany	38 (31%)	0.02 (0.22)	1.02	0.00	0.926	0.13 (0.25)	1.14	0.00	0.594	-0.22 (0.32)	0.80	0.00	0.480
African sandalwood	4 (3%)	0.99 (0.56)	2.69	0.02	0.080	0.87 (0.65)	2.39	0.01	0.181	2.59 (0.79)	13.3	0.08	**0.001***
Pine	77 (62%)	0.53 (0.20)	1.70	0.05	0.010*	0.11 (0.24)	1.12	0.00	0.639	0.62 (0.30)	1.86	0.03	**0.039***

* p<0.05

Table 4.6 (continued): Parameter estimates for inhalable particulate dust, endotoxin and glucans concentration among wood processing workers in Mozambique

Factor		Inhalable dust				Glucans				Endotoxin			
	N = 124 (%)	β (SE)	GM Ratio	r^2	p-value	β (SE)	GM ratio	r^2	p-value	β (SE)	GM ratio	r^2	p-value
State of wood													
Dry	118 (99%)	-0.03 (1.12)	0.97	0.00	0.978	1.03 (1.29)	2.80	0.01	0.430	-2.09 (1.64)	0.12	0.01	0.206
Fresh	109 (92%)	0.13 (0.37)	1.14	0.00	0.718	1.08 (0.42)	2.94	0.06	**0.011***	0.85 (0.54)	2.34	0.02	0.118
Dry and fresh	109 (92%)	0.13 (0.37)	1.14	0.00	0.360	1.08 (0.42)	2.94	0.06	0.011*	0.85 (0.54)	2.34	0.02	0.118
Building design													
Open	20 (16%)	0											
Semi-closed	36 (29%)	0.84 (0.30)	2.32	0.07	**0.006***	1.20 (0.35)	3.32	0.11	**0.001***	0.66 (0.45)	1.93	0.05	0.142
Closed	68 (55%)	0.73 (0.28)	2.08	0.07	**0.009***	0.44 (0.32)	1.55	0.11	0.165	0.97 (0.41)	2.64	0.05	**0.019***
Building size													
< 65 m^2	63 (51%)	0											
≥ 65 m^2	61 (49%)	-0.55 (0.19)	0.58	0.06	**0.005***	-0.21 (0.23)	0.81	0.01	0.365	-0.41 (0.29)	0.66	0.02	0.158
Number of workers in factory													
< 25 workers	53 (43%)	0											
≥ 25 workers	71 (57%)	-0.56 (0.20)	0.57	0.06	**0.006***	-0.36 (0.23)	0.70	0.02	0.126	-0.65 (0.29)	0.52	0.04	**0.026***
Engineering controls													
Local exhaust ventilation	40 (32%)	-0.51 (0.21)	0.60	0.00	**0.016***	-0.01 (0.25)	0.99	0.04	0.980	-0.04 (0.31)	0.96	0.00	0.894
Sharpening of cutting tools													
When necessary	64 (52%)	0											
1-3 times a week	30 (24%)	-0.26 (0.24)	0.77	0.05	0.282	-0.06 (0.28)	0.94	0.01	0.831	0.24 (0.36)	1.27	0.01	0.515
Every day	30 (24%)	-0.58 (0.24)	0.56	0.05	**0.018***	-0.34 (0.29)	0.71	0.01	0.241	-0.08 (0.36)	0.92	0.01	0.834
Wood dust cleaning methods:													
Floors													
- Dry sweeping broom	83 (67%)	-0.02 (0.21)	0.98	0.00	0.923	0.28 (0.24)	1.32	0.01	0.253	0.05 (0.31)	1.05	0.00	0.864
- Wet methods	94 (76%)	0.50 (0.23)	1.65	0.04	**0.032***	0.32 (0.27)	1.38	0.01	0.242	0.15 (0.34)	1.16	0.00	0.659
Machine maintenance													
- Damp rags	51 (41%)	-0.53 (0.20)	0.59	0.06	**0.008***	-0.74 (0.23)	0.48	0.08	**0.001***	-1.10 (0.28)	0.33	0.11	**<0.001***
- Dry rags	81 (65%)	-0.54 (0.20)	0.58	0.05	**0.009***	-0.23 (0.24)	0.79	0.01	0.336	-0.31 (0.31)	0.73	0.01	0.308
- Compressed air	64 (52%)	0.39 (0.20)	1.48	0.03	**0.053**	0.01 (0.23)	1.01	0.00	0.972	-0.09 (0.29)	0.91	0.00	0.753

* p<0.05

Table 4.6 (continued): Parameter estimates for inhalable particulate dust, endotoxin and glucans concentration among wood processing workers in Mozambique

Factor		Inhalable dust				Glucans				Endotoxin			
	N = 124 (%)	**β (SE)**	**GM Ratio**	**r^2**	**p-value**	**β (SE)**	**GM ratio**	**r^2**	**p-**	**β (SE)**	**GM ratio**	**r^2**	**p-value**
Frequency of cleaning surfaces and floors													
At end of working day	84 (68%)	0											
Twice during work shift	40 (32%)	-0.51 (0.21)	0.60	0.05	**0.016***	-0.01 (0.25)	0.99	0.00	0.980	-0.04 (0.31)	0.96	0.00	0.894
Cleaning working clothes													
When necessary	20 (16%)	0											
1-3 times per week	104 (84%)	0.77 (0.26)	2.16	0.07	**0.004***	0.70 (0.31)	2.01	0.04	**0.027***	0.86 (0.39)	2.36	0.04	**0.029***
Waste disposal													
In sealed bags	104 (84%)	0.77(0.26)	2.16	0.07	**0.004***	0.70 (0.31)	2.01	0.04	**0.027***	0.86 (0.39)	2.36	0.04	**0.029***
Placed in open containers	20 (16%)	-0.77 (0.26)	0.46	0.07	**0.004***	-0.70 (0.31)	0.50	0.04	**0.027***	-0.86 (0.39)	0.42	0.04	**0.029***
Disposed in backyard	28 (23%)	-0.39 (0.24)	0.68	0.02	0.105	-0.53 (0.28)	0.59	0.04	0.055	0.30 (0.35)	0.74	0.01	0.393
PPE provided	102 (82%)	0.48 (026)	1.62	0.03	0.068	0.48 (0.26)	1.62	0.03	0.068	0.83 (0.38)	2.29	0.04	**0.028***
Dust control training	56 (45%)	-0.19 (0.20)	0.83	0.01	0.344	0.34 (0.23)	1.40	0.02	0.141	-0.54 (0.29)	0.58	0.03	0.064

* $p<0.05$

Multivariable regression analysis

Inhalable dust particulate

Generalised linear models (GLM) for dust particulate levels (Table 4.7) only EG and working with wood species remained in the model. Exposure groups (sawing, machinery, carpentry and painting) and certain wood species (African sandalwood and Mahogany bean) were significant predictors of elevated dust particulate exposures. On the other hand, working with African teak and Panga-panga wood species were associated with lower dust levels. In the generalised estimation equation (GEE) models only EG were significantly associated with elevated dust particulate exposures in the final model. Whilst cleaning methods using damp rags was associated with lower dust levels

Endotoxins

In the generalised linear model for endotoxin levels (Table 4.8) belonging to the sawing EG, working with African sandalwood species and in closed buildings were the main predictors of elevated endotoxins. Whilst, the joinery and painting EGs, working with Panga-panga wood species and cleaning methods using damp rags were associated with lower endotoxin levels. However, in the generalized estimation equation model working with African sandalwood species was the only significant predictor of elevated endotoxin levels. Whilst, working with dry wood and cleaning methods using damp rags were associated with lower endotoxins levels.

(1-3)-β-D- glucans

Both the generalised linear model as well as generalised estimation equation model consistently demonstrated that exposure to glucans was higher in semi-closed buildings compared to open buildings, and cleaning methods using damp rags decreased glucan levels (Table 4.9).

Table 4.7: Multivariate parameter estimates for inhalable dust particulate concentrations among wood processing workers in Mozambique

	GLM (generalized linear model)			GEE (generalized estimation equation)			
Factor	**β (SE)**	**GM ratio**	**p-value**	**Factor**	**β (SE)**	**GM ratio**	**p-value**
Exposure group[a]				**Exposure group[a]**			
Sawing	1.43 (0.34)	4.18	<0.001	Sawing	1.25 (0.32)	3.49	<0.001
Machinery	0.87 (0.44)	2.39	0.047	Machinery	1.37 (0.42)	3.94	0.001
Carpentry	1.32 (0.32)	3.74	<0.001	Carpentry	1.24 (0.30)	3.46	<0.001
Painting	1.39 (0.41)	4.01	0.001	Painting	1.11 (0.42)	3.03	0.010
Wood species				**Wood dust cleaning methods**			
African sandalwood	1.16 (0.49)	3.19	0.02	Clean using damp rags	-0.60 (0.20)	0.55	0.003
Mahogany bean	1.22 (0.59)	3.39	0.04				
African teak	-0.93 (0.28)	0.39	0.001				
Panga-panga	-1.02 (0.19)	0.36	<0.001				
Intercept (constant)	0.29 (0.41)		0.478	Intercept (constant)	0.35 (0.27)		0.204

[a] Maintenance as base comparison for all other exposure groups

Table 4.8: Multivariate parameter estimates for inhalable endotoxins concentration among wood processing workers in Mozambique

	GLM (generalized linear model)			GEE (generalized estimation equation)			
Factor	**β (SE)**	**GM ratio**	**p-value**	**Factor**	**β (SE)**	**GM ratio**	**p-value**
Exposure group[a]				**Wood species**			
Sawing	0.39 (0.31)	1.48	0.199	African sandalwood	2.08 (0.76)	8.00	0.007
Joinery	-1.95 (0.52)	0.14	<0.001				
Painting	-1.15 (0.50)	0.32	0.023				
Wood species				**State of wood**			
African sandalwood	2.22 (0.77)	9.21	0.005	Dry	-2.81 (1.49)	0.06	0.062
Panga-panga	-0.62 (0.34)	0.54	0.068				
Building design[b]				**Wood dust cleaning methods**			
Closed	0.74 (0.30)	2.10	0.016	Clean using damp rags	-1.13 (0.28)	0.32	<0.001
Wood dust cleaning methods							
Clean using damp rags	-1.04 (0.30)	0.35	0.001				
Intercept (constant)	5.10 (0.37)		<0.001	Intercept (constant)	7.83 (1.50)		<0.001

[a] Maintenance as baseline for all other exposure groups
[b] Open building as base comparison for all other building designs

Table 4.9: Multivariate parameter estimates for inhalable glucans concentration among wood processing workers in Mozambique

	GLM (generalized linear model)			GEE (generalized estimation equation)			
Factor	**β (SE)**	**GM ratio**	**p-value**	**Factor**	**β (SE)**	**GM ratio**	**p-value**
Building design[b]				**Building design**[b*]			
Semi-closed	0.76 (0.24)	2.14	0.002	Semi-closed	0.76 (0.24)	2.14	0.002
Wood dust cleaning methods				**Wood dust cleaning methods**			
Clean using damp rags	-0.64 (0.22)	0.53	0.004	Clean using damp rags	-0.64 (0.22)	0.53	0.004
Intercept (constant)	4.83 (0.16)		<0.001	Intercept (constant)	4.83 (0.16)		<0.001

[b] Open building as base comparison for all other building designs

4.4 DISCUSSION

This study of workers in the Mozambique wood processing industry is the first to comprehensively characterize exposure to wood dust particulate, endotoxins and (1-3)-β-D glucans and their determinants among workers engaged in various work processes. Using various modelling techniques, this novel study demonstrated that aside from working in a similar exposure group (due to the close proximity of related jobs being physically located in the same area), working with certain wood species (African sandalwood and mahogany bean) and certain building design characteristics (closed and semi-closed buildings) were associated with higher inhalable dust particulate, endotoxins and β-glucans exposures. Whereas, working with other wood species (Panga-panga and African teak wood), and cleaning methods that used damp cloths were associated with lower exposures.

The exposure characterisation assessment component of these wood processing workers demonstrated that the mean inhalable dust particulate exposures was 3.29 mg/m^3 (GSD 3.04 mg/m^3). These dust levels are relatively high compared to international exposure standards, which generally range between 0.5-2 mg/m^3(13, 14, 15). Furthermore, they were higher than levels reported by Osman et al. (GM=2.04mg/m^3) (15), Tobin et al. (1) (1.39 mg/m^3), Straumfors et al. (16) (GM=0.72 mg/m^3), Hagström et al. (17) (GM=0.58 mg/m^3) and Douwes et al. (18) (GM=0.52 mg/m^3) in studies of furniture, sawmill and workers employed in wood pellet production, respectively. However, they were comparable to the levels reported by Rongo et al. in a study of small-scale wood industry in Tanzania (GM=3.30 mg/m^3(19) and that reported by a study among carpenters in the construction industry in the Netherlands (GM=3.30 mg/m^3) by Spee et al. (20). Interestingly they were lower than a number of African studies reported by Ayalew et al. (21) (6.82 mg/m^3), Fox (22) (GM=5.11 mg/m^3), Asgedom et al. (23) (GM=4.66 mg/m^3), Shamssain (24) (GM=3.82 mg/m^3) and Rongo et al. (25) (GM=3.78 mg/m^3).

For endotoxins, the mean exposure levels were 98 endotoxin units (EU)/m^3 (GSD 5.05). These levels are mildly elevated according to international exposure standards of 90 EU/m^3 generally used (26), and similar to the findings by Rongo et al. (19) in small-scale wood industries in Tanzania (91 EU/m^3). However, these levels are much higher than those reported by Asgedom et al. (23) observed in factories processing particle boards from eucalyptus trees in Ethiopia (62.2 EU/m^3), as well as other international studies (3, 27,28) in which the level varied between 2 and 35 EU/m^3. As for (1-3)-β-D-Glucans, mean exposures were 123 ng/m^3 (GSD 5.05 ng/m^3).

Unlike wood dust particulate and endotoxins, no exposure standards currently exist for glucans (29, 30, 31). However, it is much higher than the range of 0.1–5.2 ng/m^3 referred by Rylander (32) as being associated with increased frequency of adverse health effects in exposed populations. These levels were also higher compared to those reported by Ronald et al.(6) (0.51 – 12.6 ng/m^3), Douwes et al. (30) (0.40 – 92.5ng/m^3) and Mandryk et al. (27) (3.89 ng/m^3 in green mill and 1.91 ng/m^3 in dry mill). However, Górny et al.(31) reported even higher levels in a Polish joinery plant (176.1ng/m^3 - 394.6ng/m^3).

In this study, a modest significant positive correlation was observed between dust particulate and endotoxin concentrations (r = 0.48). A similar modest correlation between dust particulate and endotoxin was observed in the small scale wood industry in Tanzania (r = 0.44)(19) and even stronger correlations (r = 0.66) were observed in the Ethiopian study by Asgedom et al. (23) . Similar findings have been observed in other parts of world, such as the study by Fransman et al. (33)(r = 0.54), and Mandryk et al. (27) (r = 0.43). As for (1-3)-β-D-Glucans, this was also positively correlated with dust particulate in this study (r = 0.4) and slightly higher than those reported by Mandryk et al. (r = 0.31) (27). Furthermore, unlike the very high correlation observed between endotoxins and glucans in green mills (r = 0.85), this was not observed in the current study. These correlations between dust, endotoxins and (1-3)-β-D-Glucans can be probably be explained by dual nature and condition of woods processed. In this current study, a large proportion of the factories (81%) concomitantly processed dry and fresh wood. Due to the damp consistency of these woods, fungal or bacterial contamination commonly occurs when green or fresh wood is processed, as has been reported by Mandryk et al. (27).

In this study, jobs that involved painting, drilling, planing, sanding and sawing were associated with high dust particulate exposure levels, since workers in these jobs had mean exposures higher than the overall mean exposures (GM = 3.29 mg/m^3). In the final multivariate regression models revealed that belonging to certain EGs such as sawing, painting, carpentry and machinery, rather than job type wereconsistent significant predictors of increased dust particulate levels using both modelling approaches. This is due to the fact that despite doing different jobs, these workers are physically located in an open space in relatively close proximity to each other. Working in these EGs also involves greater dust production since these processes result in fine wood cells being fractured (34) due to the mechanical nature of the production process. The higher levels associated with painting, may be due to the fact that it is physically located in close proximity to the wood sanding area without any segregation, which feeds into this process. Understandably upholsterers had low dust levels, since they are dealing with a finished wood product. These findings are comparable to the small-scale wood industries in Tanzania (25) in which the highest exposures were found in carving using wood machines, cleaning workshop and repairing of wood machines. On the other hand, workers planing and sawing wood manually had lower exposures. In another study by Rongo et al. (19), the highest dust exposures were found in carving (GM = 15 mg/m^3) and cleaning operations (GM = 10 mg/m^3) but much lower levels were observed in machine planing (2 mg/m^3). The findings of the current study are similar to a Canadian study (5), which found that planing kiln-dried lumber was associated with increased exposures to wood dust particulate, jobs at the front end of the sawmill where primary breakdown of the logs is done had lower exposures. Schlunssen et al. (7) study in the Danish furniture industry also found that sanding increased dust exposure while manual assembling/packing had relatively lower exposures. Finally, a more recent joinery study by Douwes (8) found that planing, hand sawing and sanding were associated with higher exposures, while gluing (assembling) had lower wood dust particulate exposures.

Processing involving certain wood species were also significant determinants of wood dust particulate exposures. Mahogany bean (GM ratio = 3.39) and African sandalwood (GM ratio = 3.19) species were significant predictors of elevated exposures in the final multivariate generalized linear models. It is well-known that dust produced from these wood species is very fine, and is more likely to be airborne for a longer period of time. Interestingly, working with other species such as African teak and Panga-panga species were associated with lower inhalable dust particulate levels. The study by Teschke et al. (5) was the only other study that comprehensively investigated the determinants of exposure to inhalable particulate, wood dust, resin acids and monoterpenes in a lumber mill environment, which found that pine and spruce produced higher exposures than alpine or mixed tree species. In our study, the association between pine species and elevated dust exposures was only observed in the bivariate models (GM ratio = 1.70). To our knowledge, there have been no other studies that have reported significant associations between processing particular wood species and wood dust exposure levels as the current study. Further studies are needed to confirm the associations observed in other settings.

In this study, closed and semi-closed buildings were associated with high dust particulate levels in the bivariate analysis, probably due to poor ventilation. On the other hand, regular sharpening of cutting tools, use of local exhaust ventilation and larger building size, were associated with low dust levels due to less dust production and increased dust extraction and dilution effects. While these variables were associated with lower dust levels in our study, local exhaust ventilation has also been reported to be associated with lower dust levels by studies reported by Alwis (34) in Australia, Schlunssen et al. (7) in the Danish furniture industry, Cheung et al. (35) in the wood conversion sector, Kohneshahri et al. (36) in the wood door industry in west Azarbaijan and Teixeira et al. (37) in furniture factories in Brazil. Douwes (38) also demonstrated that using vacuum extraction on hand tools combined with a downdraft table reduced exposures by 42.5% for routing and 85.5% for orbital sanding. Furthermore, it has also been demonstrated that ageing equipment, poor maintenance of ventilation systems and absence of segregation of dusty processes were also predictors of higher dust levels in the wood processing industry (39).

Another important determinant of wood dust particulate levels highlighted by this current study are the cleaning procedures using compressed air for machine maintenance cleaning resulted in high dust levels due to the high pressure spreading resulting in dust dispersion. However, the study consistently demonstrated that using damp rags for cleaning was significantly associated with lower dust levels in the multivariate models. The findings of this current study are consistent with reported by Schlunssen et al.(7) in the Danish furniture industry, the intervention study by Douwes et at.(8) and the Hagström (40) studyof wood pellet production factories in Sweden, in which use of compressed air for cleaning was also associated with high wood dust levels. Other studies have also demonstrated that sweeping and dry wiping (9, 34, 37) are associated with elevated dust exposures, while use of wet methods for cleaning are associated with decreased dust levels (41). Other studies have reported that vacuum cleaning of machines and use of special cleaning staff are other predictors of decreased wood dust levels (8, 9, 38).

In this study, important determinants of exposure to endotoxins in multivariate models, included certain wood species such as African sandalwood (GM ratio = 9.21), working in closed buildings (GM ratio = 2.10) and sawing (GM ratio = 1.48). On the other hand, belonging to the joinery and painting EGs, processing Panga-panga wood species, using dry wood and cleaning using damp methods were associated with lower levels. It is understandable that African sandalwood was associated with increased exposure to endotoxins levels, since this wood species is associated with higher dust particulate levels and the modest correlation between wood dust particulate and endotoxins. Since sawing occurs in the front end stage, where wood logs are debarked, bacteria and fungi may grow more profusely on timber logs or wood chips that are stored in piles and easily disperse into air during wood processing (2). Similar findings were reported in the Norwegian sawmill industry (16), where higher levels were also found in departments where dry timber is sorted and in sawing. In Ethiopian factories processing particleboards from eucalyptus trees (23), chipping, flaking, forming and chemical/blending were associated with increasing exposure levels. Whereas in New Zealand sawmills (30), workers in the planing department had the highest mean endotoxin exposures.

The consistent major determinant for elevated inhalable (1-3)-β-D-glucan levels in multivariate models were factories that were designed as semi-closed buildings (GM ratio = 2.14), and those using damp cleaning methods with lower inhalable glucan levels. Due to their damp consistency, fungal contamination occurs on a large scale when green or fresh wood is processed. This was reported by Ronald et al. (6) in their study of four British Columbia sawmills, which demonstrated that the overall mean glucans levels in mills located in the interior were higher compared to coastal mills. Furthermore, Afanou et al. (43) also reported a higher percentage of fungal spores during summer compared to winter and that sorting of raw timber, sawing and planing had higher glucans levels.

This current study was novel and had many strengths in that it investigated a number of predictors of exposure for different components of wood dust (particulate, endotoxin and glucans) as well as the impact of processing different exotic wood species. The exposure assessments also included a component of repeated measurements of workers, which enabled assessment of intra-individual variation of exposures. Furthermore, two modelling approaches (generalized linear model and generalized estimation equation) were used in developing the multivariate models to assess the determinants of exposures, which contributed to the robustness of the findings. Furthermore, the study design also considered geographical distribution of the factories (inland versus coastal) to take into consideration whether this would impact on the dust components. This is one of few studies that has studied both endotoxins and glucan exposures in the wood processing industry and, to the best of our knowledge, the first study in Africa to undertake all these aspects.

Despite the abovementioned strengths, there were some limitations that cannot be ignored. The limited number of samples may have affected the power of study to show effects that may have not been observed in the current study. In addition, the frequency of use of different wood types also varied across the factories and may have also affected the effect estimates in relation to those that were infrequently used, resulting in the inability to demonstrate associations for these wood types. Furthermore, information on building characteristics was reliant on information obtained from the companies that could not be totally validated for logistical reasons, which may have led to reporting bias. Finally, exposure to other agents such as wood allergens, terpenes, and tannins were not measured due to logistical reasons.

4.5 CONCLUSION

This study characterizing exposure to wood dust, endotoxins and glucans among workers in the Mozambique wood processing industry and their determinants demonstrated that exposure levels for all three indices were above international standards. Processing of certain wood species (African sandalwood and mahogany bean), building characteristics, dust extraction and cleaning methods were important predictors. Furthermore, the importance of workplace dust control methods to decrease exposure have been highlighted.The findings of this study have important implications for small and medium scale enterprises involved in wood processing operations in other developing countries in the African continent and beyond.

4.6 REFERENCES

1. Tobin et al. Occupational Exposure to Wood Dust and Respiratory Health Status of Sawmill Workers in South-South Nigeria. Pollut Eff Control. 2016;4(1):4–9.
2. Gioffrè A, Marramao A, Iannò A. Airborne microorganisms, endotoxin, and dust concentration in wood factories in Italy. Ann Occup Hyg. 2012;56(2):161–9.
3. Meo SA. Effects of duration of exposure to wood dust on peak expiratory flow rate among workers in small scale wood industries. Int J Occup Med Environ Health. 2004;17(4):451–5.
4. Chamba P, Nunes E. Work-related asthma among workers in the wood-processing industry : A review. Curr Allergy Clin Immunol. 2016;29(2):110–7.
5. Teschke K, Demers PA, Davies HW, Kennedy SM, Marion SA, Leung V. Determinants of exposure to inhalable particulate, wood dust, resin acids, and monoterpenes in a lumber mill environment. Ann Occup Hyg. 1999;43(4):247–55.
6. Ronald LA, Davies HW, Bartlett KH, Kennedy SM, Teschke K, Spithoven J, et al. β (1 -3)-Glucan exposure levels among workers in four British Columbia sawmills. Ann Agric Env Med. 2003;10:21–9.
7. Vivi Schlunssen, Gitte Jacobsen, Mogens Erlandsen, Anders B. Mikkelsen IS and TS. Determinants of Wood Dust Exposure in the Danish Furniture Industry — Results from Two Cross-Sectional Studies 6 Years Apart. Ann Occup Hyg. 2008;52(4):227–38.
8. Douwes J. Wood dust in joineries and furniture manufacturing: an exposure determinant and intervention study. Ann Work Expo Heal. 2017;61(4):416–28.
9. Kenny LC, Aitken R, Chalmers C, Fabriès JF, Gonzalez-Fernandez E, Kromhout H, et al. A collaborative European study of personal inhalable aerosol sampler performance. Ann Occup Hyg. 1997 Apr;41(2):135–53.
10. Spaan S, Doekes G, Heederik D, Thorne PS, Wouters IM. Effect of extraction and assay media on analysis of airborne endotoxin. Appl Environ Microbiol. 2008;74(12):3804–11.
11. Rylander R CM. Airways inflammation among workers in poultry houses. Int Arch Occup Environ Health. 2006;79(6):487–90.
12. ACGIH. Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs). 2012. 871–1130 p.
13. The Swedish Work Environment Authority. Occupational Exposure Limit Values. 2011. 84 p.
14. Government NZ. Workplace Exposure Standards and Biological Exposure Indices. 2018.

68 p.

15. Osman E, Pala K. Occupational exposure to wood dust and health effects on the respiratory system in a minor industrial estate in Bursa, Turkey. Int J Occup Med Environ Health. 2009;22(1):43–50.
16. Anne Straumfors, Raymond Olsen, Hanne Line Daae AA, Dave McLean, Marine Corbin, Andrea ‘t Mannetje BU, Berit Bakke, Helle Laier Johnsen JD and WE. Exposure to Wood Dust, Microbial Components, and Terpenes in the Norwegian Sawmill Industry. Ann Work Expo Heal. 2018;20(20):1–15.
17. Hagström K, Axelsson S, Arvidsson H, Bryngelsson I, Eriksson K, Hagstr K. Exposure to Wood Dust , Resin Acids , and Volatile Organic Compounds During Production of Wood Pellets. J Occup Environ Hyg. 2008;5:296–304.
18. Douwes J, Mclean D, Slater T, Travier N, Cheng S, Pearce N. Pine dust, atopy and lung function: a cross- sectional study in sawmill workers. Eur Respir J. 2006;28:791–8.
19. Rongo LMB, Msamanga GI, Burstyn I, Barten F, Dolmans WM V, Heederik D. Exposure to wood dust and endotoxin in small-scale wood industries in Tanzania. J Expo Anal Environ Epidemiol. 2004;14(7):544–50.
20. Spee T, van de Rijdt-van Hoof E, van Hoof W, Noy D, Kromhout H. Exposure to wood dust among carpenters in the construction industry in the Netherlands. Ann Occup Hyg. 2007;51(3):241–8.
21. Ayalew E, Gebre Y, De Wael K. A survey of occupational exposure to inhalable wood dust among workers in small-and medium-scale wood-processing enterprises in Ethiopia. Ann Occup Hyg. 2015;59(2):253–7.
22. Fox FH. An Epidemiological Survey of Asthma in a Pine Sawmill in South Africa. 2004.
23. Awealom Asgedom, Magne Bråtveit, Vivi Schlünssen BEM. Exposure to inhalable dust, endotoxin and formaldehyde in factories processing particleboards from eucalyptus trees in Ethiopia. Env Occup Heal Pract. 2020;1–10.
24. Shamssain MH. Pulmonary function and symptoms in workers exposed to wood dust. Thorax [Internet]. 1992;47(2):84–7.
25. Rongo LMB, Besselink A, Msamanga GI, Dolmans WM V, Demers PA, Heederik D. Respiratory Symptoms and Dust Exposure Among Male Workers in Small-Scale Wood Industries in Tanzania. J Occup Environ Med. 2002;44(12):1153–60.
26. Health Council of the Netherlands. Endotoxins. Health-based recommended occupational exposure limit. publication no. 2010/04OSH. 2010. 100 p.
27. Mandryk J, Alwis KU, Hocking AD. Effects of Personal Exposures on Pulmonary Function

and Work-related Symptoms Among Sawmill Workers. Ann Occup Hyg. 2000;44(4):281–9.

28. Dutkiewicz J, Krysinska-Traczyk E, Prazmo Z, Skorska C SJ. Exposure to airborne microorganisms in Polish sawmills. Ann Agric Env Med. 2001;8:71–80.
29. Ławniczek-wałczyk A, Górny RL. Endotoxins and β-glucans as markers of microbiological contamination – characteristics, detection, and environmental exposure. Ann Agric Env Med. 2010;17:193–208.
30. Douwes J, McLean D, Van Maarl E Der, Heederik D, Pearce N. Worker exposures to airborne dust, endotoxin and β(1,3)-glucan in two New Zealand sawmills. Am J Ind Med. 2000;38(4):426–30.
31. Rafał L. Górny, Anna Ławniczek-Wałczyk, Marcin Cyprowski, Małgorzata Gołofit-Szymczak, Agata Stobnicka AB, Laboratory. Wood dust as a source of microbial contamination at joinery. J Int Sci Publ. 2017;11:150–64.
32. Rylander R. Indoor Air-Related Effects and Airborne (1→3)-β-D-Glucan. Environ Health Perspect. 1999;107(3):501–3.
33. Fransman et al. Respiratory Symptoms and Occupational Exposures in New Zealand Plywood Mill Workers. Ann Occup Hyg. 2003;47(4):287–295.
34. Alwis KU. Occupational exposure to wood dust. The University of Sydney; 1998.
35. Kerry Cheung, David McLean, Neil Pearce JD. Exposures to hazardous aiborne substances in the Wood Conversion Sector. Centre for Public Health Research, Massey University. 2010;125.
36. Kohneshahri MH, Mohammadyan M, Khani HM, Pourhossein M, Dastakzan B. Designing a Local Exhaust Ventilation System to Control Toluene Diisocyanate and Dust in Woodworking Industries. Int J Occup Hyg. 2008;8(4):223–9.
37. Teixeira RL, Silva JRM da, Fiedler NC, Lima JT, Trugilho PF, Neri AC. Evaluation of Airborne MDF Dust Concentration in Furniture Factories. Floresta e Ambient. 2017;24:6.
38. Challenge E. American Thoracic Society Guidelines for Methacholine and Exercise Challenge Testing -1999. 1999;(10).
39. Alwis U, Mandryk J, Hocking AD, Lee J, Mayhew T, Baker W. Dust exposures in the wood processing industry. Am Ind Hyg Assoc J. 1999;60(5):641–6.
40. Hagström K. Occupational exposure during production of wood pellets in Sweden. 2008. 78 p.
41. California Department of Public Health. Wood Dust and Work-related Asthma. 2017.
42. Mikkelsen AB. Determinants of Wood Dust Exposure in the Danish Furniture Industry.

Ann Occup Hyg. 2002;46(8):673–85.

43. Afanou KA, Eduard W, Laier Johnsen HB, Straumfors A. Fungal Fragments and Fungal Aerosol Composition in Sawmills. Ann Work Expo Heal. 2018;62(5):559–70.

APPENDICES – ADDITIONAL ANALYSIS

GENERALIZED ESTIMATION EQUATION (GEE) REGRESSION

Table 4.10: Parameter estimates for inhalable dust, glucans and endotoxin concentration among wood processing workers in Mozambique

Factor		Inhalable dust				Glucans				Endotoxin			
	N = 124 (%)	β (SE)	GM Ratio	r^2	p-value	β (SE)	GM ratio	r^2	p-value	β (SE)	GM ratio	r^2	p-value
Province													
Maputo City	10 (8%)	0				0				0			
Maputo	55 (44%)	-0.27 (0.54)	0.76	0.03	0.624	-0.14 (0.55)	0.87	0.08	0.806	-1.47 (0.78)	0.23	0.08	**0.061**
Sofala	59 (48)	-0.52 (0.54)	0.59	0.03	0.334	-0.83 (0.55)	0.44	0.08	0.132	-1.96 (0.78)	0.14	0.08	**0.011***
Factory													
SECAMA	15 (12%)	0											
Carpintaria SB	10 (8%)	-0.09 (0.60)	0.91	0.11	0.874	-0.45 (0.52)	0.64	0.22	0.385	2.20 (0.84)	9.03	0.19	**0.009***
Yola Mobilias	20 (16%)	-0.44 (0.51)	0.64	0.11	0.388	-1.21 (0.44)	0.30	0.22	**0.005***	0.99 (0.72)	2.69	0.19	0.167
Luxoflex	20 (16%)	-0.49 (0.52)	0.61	0.11	0.352	-0.35 (0.44)	0.70	0.22	0.428	1.30 (0.73)	3.67	0.19	**0.074**
Industria Madereira	11 (9%)	-0.68 (0.58)	0.51	0.11	0.236	-0.56 (0.50)	0.57	0.22	0.264	0.27 (0.81)	1.31	0.19	0.739
Mutende	10 (8%)	-0.41 (0.63)	0.66	0.11	0.512	-1.33 (0.53)	0.26	0.22	**0.011***	-0.06 (0.88)	0.94	0.19	0.949
Fim da Vida	8 (7%)	0.14 (0.60)	1.15	0.11	0.814	-0.88 (0.54)	0.41	0.22	0.104	1.61 (0.84)	5.00	0.19	**0.057**
LevasFlor	20 (16%)	-1.09 (0.52)	0.34	0.11	**0.037***	-1.49 (0.44)	0.23	0.22	**0.001***	-0.08 (0.73)	0.92	0.19	0.915
Movarte	10 (8%)	-0.52 (0.63)	0.59	0.11	0.404	-1.91 (0.53)	0.15	0.22	<**0.001***	-0.10 (0.88)	0.90	0.19	0.914
Exposure group													
Maintenance	5 (4%)	0											
Sawing	36 (29%)	1.54 (0.73)	4.66	0.13	**0.034***	0.28 (0.92)	1.32	0.02	0.759	1.61 (1.21)	5.00	0.05	0.182
Machinery	10 (8%)	1.64 (0.84)	5.16	0.13	**0.051***	0.39 (1.06)	1.48	0.02	0.715	1.36 (1.39)	3.90	0.05	0.329
Carpentry	53 (43%)	1.58 (0.71)	4.85	0.13	**0.027***	0.44 (1.55)	1.55	0.02	0.630	1.16 (1.19)	3.19	0.05	0.327
Joinery	10 (8%)	0.48 (0.82)	1.62	0.13	0.556	0.86 (1.03)	2.36	0.02	0.403	0.34 (1.35)	1.40	0.05	0.799
Painting	10 (8%)	1.69 (0.84)	5.42	0.13	**0.044***	-0.05 (1.06)	0.95	0.02	0.960	0.90 (1.39)	2.46	0.05	0.517
Job title													
Machine repair	5 (4%)	0											
Planer	21 (17%)	1.68 (0.76)	5.37	0.13	**0.028***	0.21 (0.94)	1.23	0.03	0.824	1.72 (1.23)	5.58	0.07	0.160
Sawyer	36 (29%)	1.54 (0.73)	4.66	0.13	**0.035***	0.28 (0.91)	1.32	0.03	0.757	1.61 (1.18)	5.00	0.07	0.173
Driller	10 (8%)	1.64 (0.85)	5.16	0.13	**0.053***	0.39 (1.04)	1.48	0.03	0.711	1.36 (1.36)	3.90	0.07	0.317
Sander	32 (26%)	1.51 (0.74)	4.53	0.13	**0.041***	0.58 (0.91)	1.79	0.03	0.524	0.80 (1.19)	2.23	0.07	0.499
Painter	10 (8%)	1.69 (0.85)	5.42	0.13	**0.046***	-0.05 (1.04)	0.95	0.03	0.960	0.90 (1.36)	2.46	0.07	0.507
Upholsterer	10 (8%)	0.48 (0.83)	1.62	0.13	0.563	0.85 (1.02)	2.34	0.03	0.400	0.35 (1.32)	1.42	0.07	0.793
Wood species													
Mahogany bean	119 (96%)	0.94 (0.78)	2.56	0.03	0.230	-0.51 (0.86)	0.60	0.01	0.552	1.00 (1.17)	2.72	0.01	0.393
African teak	104 (84%)	-0.44 (0.42)	0.64	0.02	0.286	-0.29 (0.45)	0.75	0.01	0.516	0.80 (2.23)	2.23	0.03	0.191
Panga	84 (68%)	-0.49 (0.30)	0.61	0.07	**0.096***	-0.23 (0.35)	0.79	0.01	0.519	-0.45 (0.46)	0.64	0.04	0.326
Lebombo ironwood	22 (18%)	0.48 (0.37)	1.62	0.01	0.191	0.49 (0.39)	1.63	0.03	0.211	1.13 (0.54)	3.10	0.04	**0.036***
African mahogany	38 (31%)	0.16 (0.32)	1.17	0.00	0.626	0.11 (0.35)	1.12	0.00	0.757	0.06 (0.48)	1.06	0.00	0.897
African sandalwood	4 (3%)	0.99 (0.81)	2.69	0.02	0.224	0.82 (0.88)	2.27	0.01	0.356	2.55 (1.13)	12.81	0.08	**0.025***
Pine	77 (62%)	0.52 (0.29)	1.68	0.05	0.078	0.14 (0.34)	1.15	0.00	0.685	0.70 (0.45)	2.01	0.03	0.116*

Table 4.10 (continued): Parameter estimates for inhalable dust, glucans and endotoxin concentration among wood processing workers in Mozambique

Factor	Inhalable dust					Glucans				Endotoxin			
	N = 124 (%)	**β (SE)**	**GM Ratio**	**r^2**	**p-value**	**β (SE)**	**GM ratio**	**r^2**	**p-value**	**β (SE)**	**GM ratio**	**r^2**	**p-value**
State of wood													
Dry	118 (99%)	-0.14 (0.94)	0.87	0.00	0.879	0.35 (1.15)	1.42	0.01	0.761	-3.09 (1.34)	0.05	0.01	**0.021***
Fresh	109 (92%)	0.14 (0.58)	1.15	0.00	0.814	1.13 (0.59)	3.10	0.06	**0.057**	0.89 (0.85)	2.44	0.02	0.292
Dry and fresh	109 (92%)	0.14 (0.58)	1.15	0.00	0.814	1.13 (0.59)	3.10	0.06	**0.057**	0.89 (0.85)	2.44	0.02	0.292
Building design													
Open	20 (16%)	0											
Semi-closed	36 (29%)	0.85 (0.44)	2.34	0.07	0.056	1.20 (0.45)	3.32	0.11	**0.008***	0.80 (0.67)	2.23	0.05	0.236
Closed	68 (55%)	0.72 (0.41)	2.05	0.07	0.080	0.48 (0.42)	1.62	0.11	0.256	0.96 (0.63)	2.61	0.05	0.125
Building size													
< 65 m^2	63 (51%)	0											
≥ 65 m^2	61 (49%)	-0.54 (0.28)	0.58	0.06	0.056	-0.28 (0.33)	0.76	0.01	0.393	-0.49 (0.44)	0.61	0.02	0.262
Number of workers in factory													
< 25 workers	53 (43%)	0											
≥ 25 workers	71 (57%)	-0.54 (0.28)	0.58	0.06	0.056	-0.28 (0.33)	0.76	0.02	0.393	-0.49 (0.44)	0.61	0.04	0.262
Engineering controls													
Local exhaust ventilation	40 (32%)	-0.50 (0.31)	0.60	0.00	0.114	-0.09 (0.36)	0.91	0.04	0.797	-0.11 (0.49)	0.90	0.00	0.817
Sharpening of cutting tools													
When necessary	64 (52%)	0											
1-3 times a week	30 (24%)	-0.21 (0.36)	0.81	0.05	0.560	-0.13 (0.41)	0.88	0.01	0.757	0.26 (0.57)	1.30	0.01	0.651
Every day	30 (24%)	-0.42 (0.35)	0.66	0.05	0.227	-0.33 (0.40)	0.72	0.01	0.406	-0.24 (0.55)	0.27	0.01	0.663
Wood dust cleaning methods:													
Floors													
- Dry sweeping with broom	83 (67%)	-0.13 (0.32)	1.14	0.00	0.689	0.22 (0.34)	1.25	0.01	0.529	0.24 (0.47)	1.27	0.00	0.611
- Wet methods	94 (76%)	0.36 (0.34)	1.43	0.04	0.288	0.30 (0.38)	1.35	0.01	0.439	-0.17 (0.53)	0.84	0.00	0.750
Machine maintenance													
- Damp rags	51 (41%)	-0.53 (0.29)	0.59	0.06	0.071	-0.75 (0.30)	0.47	0.08	**0.014***	-1.12 (0.40)	0.33	0.11	**0.006***
- Dry rags	81 (65%)	-0.44 (0.29)	0.64	0.05	0.133	-0.28 (0.34)	0.76	0.01	0.408	-0.16 (0.45)	0.85	0.01	0.729
- Compressed air	64 (52%)	0.28 (0.29)	1.32	0.03	0.334	0.06 (0.33)	1.06	0.00	0.857	-0.26 (0.45)	0.77	0.00	0.564
Frequency of cleaning surfaces and floors													
At end of working day	84 (68%)	0											
Twice during work shift	40 (32%)	-0.50 (0.31)	0.61	0.05	0.114	-0.09 (0.36)	0.91	0.00	0.797	-0.11 (0.49)	0.90	0.00	0.817

* p<0.05

Table 4.10 (continued): Parameter estimates for inhalable dust, glucans and endotoxin concentration among wood processing workers in Mozambique

Factor		Inhalable dust				Glucans				Endotoxin			
	N = 124 (%)	**β (SE)**	**GM Ratio**	**r^2**	**p-value**	**β (SE)**	**GM ratio**	**r^2**	**p-**	**β (SE)**	**GM ratio**	**r^2**	**p-value**
Cleaning working clothes													
When necessary	20 (16%)	0											
1-3 times per week	104 (84%)	0.77 (0.40)	2.16	0.07	**0.053**	0.75 (0.44)	2.14	0.04	**0.093**	0.90 (0.61)	2.46	0.04	0.137
Waste disposal													
In sealed bags	104 (84%)	0.77(0.40)	2.16	0.07	**0.053**	0.75 (0.44)	2.12	0.04	**0.093**	0.90 (0.61)	2.46	0.04	0.137
Placed in open containers	20 (16%)	-0.77 (0.40)	0.46	0.07	**0.053**	-0.75 (0.47)	0.47	0.04	**0.093**	-0.90 (0.61)	0.41	0.04	0.137
Disposed in backyard	28 (23%)	-0.25 (0.35)	0.78	0.02	0.465	-0.53 (0.38)	0.59	0.04	0.162	-0.18 (0.52)	0.84	0.01	0.731
PPE provided	102 (82%)	0.50 (039)	1.65	0.03	0.197	0.48 (0.42)	1.62	0.03	0.248	0.85 (0.56)	2.34	0.04	0.131
Dust control training	56 (45%)	-0.14 (0.30)	0.87	0.01	0.647	0.33 (0.32)	1.39	0.02	0.310	-0.41 (0.43)	0.66	0.03	0.336

* p<0.05

CHAPTER 5

RESPIRATORY SYMPTOMS, AIRWAY INFLAMMATION AND LUNG FUNCTION OF WORKERS IN THE MOZAMBIQUAN WOOD PROCESSING INDUSTRY

ABSTRACT

Background: Inhalation of wood dust particulate and its different bioaerosol and chemical components result in airway responses that are either sensitizing or irritative in nature. Studies in the wood processing industry have demonstrated an increased risk of respiratory symptoms and asthma in exposed workers. Studies of wood workers on the African continent have also investigated the respiratory health effects in workers exposed to different indigenous wood species. However, there have been no studies previously conducted in Mozambique. The aim of this study was to assess the prevalence of respiratory symptoms, lung function and airway inflammation among workers in the Mozambique wood processing industry.

Methods: A cross-sectional study of 450 wood processing workers was conducted in 21 factories from three provinces of Mozambique. Each worker completed a modified version of the European Community Respiratory Health Survey (ECRHS) that included occupational histories and related exposures. Sera from 391 participants was collected and analyzed for specific immunoglobulin E (sIgE) antibody reactivity to common aero-allergens (Phadiatop). Fractional exhaled nitric oxide (FeNO) testing was conducted on 443 during the working day prior to spirometry (n=435), which was accompanied by a post-bronchodilator test (n=423).

Results: The mean age of study participants, who were predominantly male workers, was 38 years. A large proportion of workers were non-smokers (76%) and 48% were atopic.Their average overall employment duration was 9 years, of which 7 years was held in the current job.Almost half the study population reported excessive wood dust production in their jobs within one meter of the source. Ocular-nasal symptoms were reported by 34% of workers, while 10% had an asthma symptom score ≥ 2. Work-related ocular-nasal symptoms (40%) were also more common than work-related chest symptoms (14%). Wood dust was reported as a main cause of ocular-nasal (36%) and chest symptoms (12%). The most commonly used woods by workers were African teak and Mahogany bean (75%), followed by Panga-panga (55%) and Pine (42%).There were 19% of subjects with evidence of airflow obstruction, 6% with bronchial reversibility indicative of asthma and 14% with fixed airway obstruction, suggestive of chronic obstructive pulmonary disease (COPD). In this population, there were 23% of workers with borderline elevated FeNO (25–50 ppb) and 5% with high (>50 ppb) levelsindicative of underlying airway inflammation. A significant positive correlation was found between bronchial reversibility and FeNO for levels ≥50 ppb. Among the asthma phenotypes the prevalence of current asthma in this population was 7%, with equal proportions of atopic and non-atopic asthma (4%), and 2% having work-related asthma.

Conclusion: This study has demonstrated that workers in the Mozambique wood processing industry have a high burden of obstructive lung disease, including asthma, with work-related factors playing an important role. The most commonly used species used were African teak, Mahogany bean and Panga-panga. The prevalence of asthma found in this study, is on the upper end of estimates of that observed in other African wood working populations. Both allergic and non-allergic asthma phenotypes are prevalent in similar proportions.

5.1 INTRODUCTION

Inhalation of wood dust particulate and its different bioaerosol and chemical components enter the upper and lower airways resulting in airway responses and symptoms, which could either be of a sensitizing or irritating nature (1). Wiggans et al.(2), in their systematic review of the literature demonstrated that work in the furniture and wood processing industry is associated with a significantly increased risk of respiratory symptoms and asthma (2). A meta-analysis of wood dust exposure and asthma risk reported a pooled relative risk (RR) of 1.53 (95% CI 1.25–1.87) (3). When the analysis was restricted to studies conducted on Caucasian populations, the pooled RR was 1.59 (95% CI 1.26–2.00) and lower in Asian populations. The global prevalence of asthma in woodworkers is between 5.6 and 18% (3,4, 5, 6), while its prevalence in Africa appears to be lower, between 3 and 7% (8). The prevalence of rhinitis, as expected is much higher ranging between 16-33%. (8) . There have been various studies that have identified specific wood species such as Pine, Mahogany, African teak, Red cedar and Imbuia being associated with a relatively higher prevalence of asthma and rhinitis. Furthermore, fibre- and chipboards and *Mansonia* wood species are associated with a high prevalence of rhinitis.

There are a few studies in Africa that have investigated the respiratory health effects in wood workers exposed to different species of woods, based on their geographical context. The earliest study was conducted by Shamssain (9) in South African workers (n=145) employed in a furniture factory, which reported a high prevalence of lower respiratory symptoms (15-40%) and wheezing (13%). Subsequently, Fox (10) investigated sawmill workers (n=392) exposed to pine wood dust and reported prevalence of asthma ranging from 0.5% (definite), 2.6% (probable) and 10.2% (possible).

On the east coast of Africa, Tanzanian studies by Rongo et al., (11) in small-scale wood industries in Tanzania (n=546) reported even similar prevalence of lower respiratory symptoms (47-51%) and wheezing (9.4%) that were higher than nasal symptoms (11.0%). More recently, Asgedom et al. (12) reported that particle board workers in Ethiopia (n=74) had a higher prevalence of lower respiratory symptoms (24-39%) as well as wheezing (45%) compared water bottling workers. Furthermore, Fentie et al.(1) study of woodworkers in Southwest Ethiopia (n=70), also found a similar prevalence of lower respiratory symptoms (34-41%).

On the west coast of Africa, Ugheoke et al. (13) study of Nigerian sawmill workers in Benin City (n=150) also reported a high prevalence of lower respiratory symptoms (9-55%) but a lower prevalence of wheeze (4%). Another study of wood workers (n=591) in South-Eastern Nigeria by Aguwa et al. (14) found a very high prevalence of occupational rhinitis (78%) compared to occupational asthma (6.5%). More recently, Tobin et al.(15) investigated sawmill workers (n=227) in South-South Nigeria and a similar range of lower respiratory symptom prevalence (7-50%) and wheeze (5%), that were significantly higher than the comparison group. Mumuni (16), investigating respiratory health problems among sawmill workers (n=155) in Ghana found a much higher prevalence ofcough (77%), wheezing, (48%), tightness of chest (48%), shortness of breath (53%), and phlegm production (61%). Finally, a study of informal sector wood workers in Cameroon (n=135) by Nde et al. (17) reported very similar prevalence of cough (34.5%) and rhinitis (30%) that were that were higher than non-exposed workers.

Despite a high prevalence of respiratory symptoms and associated respiratory disease burden including asthma in wood workers globally, the pathophysiological mechanisms that underlie the basis for wood dust induced asthma are far from being fully understood (18). For Red Cedar, a unique constituent, plicatic acid, has been shown to be the causative agent, indicating that both immunological and non-immunological mechanisms are involved. For other types of wood, no clear aetiological agent has been consistently reported. While specific IgE sensitization has been reported in asthma among woodworkers (18), Type 1 allergy is not suspected to be the major mechanism involved. Formaldehyde-based stabilizers used in wood composite manufacture have also been implicated as respiratory sensitizers. While isolated studies have identified allergic disease mechanisms associated for some specific wood species, a single unifying immunological mechanism has yet to be described (2). Apart from IgE mediated sensitization, other mechanisms, including that of an irritative nature have been suggested (18).

In more recent years, the role of airway inflammation has also been highlighted through the measurement of exhaled nitric oxide (FeNO) levels. Wiggans et al. (19) study of British woodworkers (n=269) reported that 18% of subjects had high (≥40 ppb) FeNO levels. Almugally et al. (20) also reported a significant increase in FeNO (33 ppb) in Saudi Arabian wood workers compared to controls (9 ppb), suggesting these changes to be due to prolonged exposure to wood dust. However, Paraskevaidou et al. (21) study of Greek furniture workers found that only 5 out of 83 subjects demonstrated FeNO levels above 25 ppb. A more detailed characterisation of these airway inflammatory responses, taking into account other determinants needs further elucidation.

The aim of this study was to determine the prevalence of work-related respiratory symptoms including rhinitis and asthma, lung function impairment and the determinants of elevated FeNO so as to better characterise asthma phenotypes among workers in the Mozambique wood processing industry.

5.2 METHODS

5.2.1 Study population and sampling

The study population was drawn from three major sites that included Maputo City where 142 furniture/joinery workers were employed in 12 factories, Maputo Province having 76 workers employed in 3 factories and Sofala Province with 232 furniture/joinery workers employed in 6 factories. Employers of selected factories were contacted prior to the recruitment and permission obtained to address the workers. The meeting with workers was arranged to explain the purpose of the study, invite workers to participate in the study and provide them with a consent form (Appendix 1) and pretest instructions (Appendix 2). Those who agreed to participate underwent the health outcome assessments that were conducted at the work site during work time. Overall, 450 of 513 workers participated in the study, representing an 88% response rate.

The health outcome assessment entailed an interviewer-administered questionnaire, exhaled nitric oxide (FeNO), spirometry accompanied by bronchial reversibility testing and allergy testing (Phadiatop).

5.2.2 Questionnaire

Each worker completed a standard interviewer-administered questionnaire of the European Community Respiratory Health Survey (ECRHS) for the investigation of asthma. The questionnaire was modified to include questions relating to current and previous employment, exposure to wood dust, types of wood the worker is exposed to, information regarding the origin of the wood species processed, detail on chemical and pesticide treatment (Appendix 3).

The questionnaire was translated into Portuguese and back translated to English to verify translation correctness. Interviews in Maputo City and Maputo Province were conducted by recently graduated physicians from Faculty of Medicine of Eduardo Mondlane University and in Sofala Province by a nurse and preventive medicine technician, all of whom received appropriate training prior to the study. Smoking status was classified into three categories: non-smoker as lifelong abstinence from smoking; ex-smoker if ceased smoking completely more than 1-month before the survey; and current smoker. Symptom variables included respiratory (wheeze and tightness in the chest, shortness of breath, cough and phlegm from the chest) and nasal (runny nose, blocked nose, stuffy nose) symptoms.

An asthma symptom score was computed based on the sum of answers (0=no, 1=yes) to five questions on asthma-like symptoms in the past 12 months (short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath), as has been described previously (22,23). A binary variable was created from these five asthma-like symptoms (≥ 2 symptoms vs 0-1 symptom). Having ≥ 2 asthma-like symptoms was considered 'more symptomatic' and 0-1 asthma-like symptom 'less symptomatic'.

Work-related asthma was defined as having an asthma attack in the past 12 months, current use of asthma medication or woken up by an attack of shortness of breath in the past 12 months; and work-related chest symptoms in the past 12 months that gets better when away from work or worsen on return to work.

Occupational rhinitis was defined as work-related specific symptom/s such as nasal congestion, itching, sneezing and rhinorrhea.

5.2.3 Test for atopy (Phadiatop)

A blood sample (9 ml) was drawn from each participant using a Becton Dickinson Vacutainer SST tube (with gel medium and clot activator) bya qualified laboratory technologist. The blood was allowed to clot for 1-2 hours at room temperature (20-24 degrees Celsius) and then centrifuged at 1350 rpm for 10 minutes at room temperature at the Laboratory of the Centre of Medical Examinations of Maputo (for the samples collected in Maputo City and Maputo

Province) and at the Laboratory of Medical Centre of Munhava and Medical Centre of Muanza (for the samples collected in Sofala Province). The sera were then transferred into micro-vials and stored at -70 degrees Celsius at the Laboratory of Central Hospital of Maputo (for the samples collected in Maputo City and Maputo Province). The serum samples collected in Sofala Province were initially stored at -20 degrees Celsius at the Laboratory of Medical Centre of Ponta Gea in Beira City and then transported on dry ice to Maputo City where they were stored at -70 degrees Celsius at the Laboratory of Central Hospital until they were analyzed further. The stored serum samples were then finally transported on dry ice to the University of Cape Town laboratories where they were stored at minus 80 degrees Celsius prior to being couriered to the SANAS accredited (ISO 15189:2007), National Institute for Occupational Health (NIOH) Immunology laboratory for further analysis. The presence of sensitization to common aeroallergens (house dust mites, grass pollens, cat, dog, and cockroach) was determined using the Phadiatop® test (Phadia AB, Uppsala, Sweden), as it has been used extensively in evaluation of common inhalant allergy of individuals residing in the Southern African region, since it has a high degree of sensitivity for detecting atopy A positive result was classified as any value ≥0.35 ku/L. Preliminary in vivo immunological studies of sera obtained from symptomatic workers to the commonly processed wood species by workers were unable to demonstrate IgE responses to these woods.

5.2.4 Spirometry and post-bronchodilator response (PBR)

Spirometry accompanied by bronchodilator challenge was considered to be the simplest technique with well established objective outcomes to use in this setting to identify individuals with underlying asthma. All workers were subjected to spirometry following American Thoracic Society (ATS)/ERS guidelines for conducting spirometry (24). The EasyOne Spirometer was used. It utilizes digital ultrasonic flow measurement technology, repeatable performance and quality control without the need for calibration or maintenance, thereby ensuring accurate results. Recently graduated physicians, a nurse and preventive medicine technician conducted the spirometry after undergoing training to ensure good quality spirograms. An average of 10 workers underwent spirometry each day. Spirometry was performed in a sitting position without nose clips. Each worker performed up to eight trials to produce three acceptable curves. Test reproducibility was used as a guide as to whether further attempts were necessary. A quality control sheet was used to assess the quality of spirograms before the data was analysed. The information outlined in Table 5.1 presents the ATS/ERS quality categories that were used (25).

Poor reproducibility may also be an independent marker of airway dysfunction, hence all spirometry tests with ATS quality grade F were not included in the analysis.

Table 5.1: Grading System for FEV_1 and FVC (Graded Separately)

Grade	Number of measurements	Repeatability: Age >6 yr
A	≥3 acceptable	Within 0.150 L
B	2 acceptable	Within 0.150 L
C	≥2 acceptable	Within 0.200 L
D	≥2 acceptable	Within 0.250 L
E	≥2 acceptable	>0.250 L
	OR 1 acceptable	Note applicable
U	0 acceptable AND ≥1 usable	Note applicable
F	0 acceptable and 0 usable	Note applicable

Source: ATS/ERS (2019)

The lung function indices of primary interest included forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1). The best FEV_1 and FVC were used regardless of whether they belonged to the same tracing. The GLI-2012 reference values were used for spirometry interpretation, with lower limits corresponding to the 95th percentile. Heights and weights of workers were recorded for calculating predicted lung function indices using GLI equations. The timing of spirometry was during the working dayfrom Monday to Friday. Special instructions to workers to ensure that tested individuals did not smoke tobacco (at least 2 hours before) nor did they take any anti-asthmatic inhalers (12 hours before) or oral asthma medications (48 hours before) prior to the test (Appendix 4). The results of spirometry and BDR tests were recorded on lung function test data collection sheets (Appendix 5). The BDR response was analysed using two approaches as described previously (26)(27).

5.2.5 Fractional Exhaled Nitric Oxide (FeNO)

The instantaneous on-line exhaled fractional exhaled nitric oxide (FeNO) monitoring method was performed according ATS/ERS recommendations for standardized measurement of (28). The recommended technique for adult patients involved inspiration of NO-free air via a mouthpiece to total lung capacity, followed immediately by full exhalation at an even rate through the mouthpiece into the apparatus. A hand-held portable nitric oxide sampling device (NIOX MINO® Airway Inflammation Monitor (NIOX MINO); Aerocrine AB, Solna, Sweden) was used for this purpose. The fieldworkers were trained to conduct the FeNO measurements prior to the study. The worker was seated comfortably, with the mouthpiece at the proper height and position. A nose clip was not used as this may allow nasal NO to accumulate and promote leakage of this NO via the posterior nasopharynx. The worker inserted a mouthpiece and inhaled over 2 to 3 seconds through the mouth to total lung capacity (TLC), and then exhaled immediately, since breath holding could affect FeNO. Two technically adequate measurements were performed. If the measurements differed by 10ppb or more, a third measurement was performed, and the mean of all three measurements was used.

Special instructions were provided to workers to ensure that tested individuals did not smoke tobacco, eat or drink (at least 1 hour before) prior to the test (Appendix 2). Ambient NO and temperature was also recorded (Appendix 6). Since spirometry may impact on FeNO, the test was performed before spirometry during the work shift.

A measurement for FeNO > 50 ppb in adults in the absence of a recent upper respiratory tract infection suggested the presence of underlying airway inflammation as is commonly observed in allergic asthma (29).

5.2.6 Statistical analysis

All statistical analysis was performed using STATA version 12 (StataCorp, College Station, TX, USA). In this study, both continuous and categorical analyses were conducted. Frequencies and percentages were used to summarize categorical variables, whilst the mean and standard deviation (and where appropriate median and interquartile range) was used for numerical variables. Unadjusted linear and logistic regression was used to investigate the association between continuous indices of bronchial reversibility (BDR – bronchodilator response) and airway inflammation (FeNO).

5.3 RESULTS

5.3.1 Demographic characteristics

The mean age of workers in this study was 38 years, predominantly male (94%) and a large proportion were non-smokers (76%) (Table 5.2). Workers involved in wood processing jobs comprised 64% of the study population. Workers were, on average employed in the factory for almost nine years and in their current job for seven years. With regard to a previous history of lung disease, 6% reported being treated previously for tuberculosis and 4% had repeated childhood chest infections. Overall, a family history of allergy was reported by 35% of workers, whereas 48% were found to be atopic, testing positive on the Phadiatop test or reported a family history of allergy.

5.3.2 Current job exposure characteristics

Workers in the wood processing industry handled several types of woods (Table 5.3), the most common being African teak *(Pterocarpus angolensis DC)* andMahogany bean *(Afzelia quanzensis Welw.)* (75%), followed by Panga-panga *(Millettia Stuhlmannii Taub)* (55%) and Pine *(Pinus sp)* (42%). Aside from using different wood species, workers were also exposed to various chemicals, the most common being glues (36%) and varnishes (23%). Almost half the workforce (46%) reported that their current job produced a lot of wood dust as did (52%) that worked right next to the source (<1 meter). Most workers (89%) reported using some form of personal protective equipment (PPE) on a regular basis, the most common being masks (85%).

5.3.3 Asthma history and respiratory symptoms

There were 11% of the workforce that reported ever having had asthma (Table 5.4), and doctor-diagnosed asthma was reported in 6% of study participants. The prevalence of asthma-related symptoms in the last 12 months varied from 2% (shortness of breath) to 15% (wheezing, chest tightness awakening). These figures are very similar to the 10% prevalence computed for those having an asthma symptom score ≥2. The study also found that a much higher proportion (34%) of subjects had ever experienced ocular-nasal symptoms.

Table 5.2: Demographic characteristics of wood processing workers in Mozambique

Demographic characteristic	**Prevalence (%) n = 450**
Age (years)	38 ± 13
Gender (%Male vs Female)	94 : 6
BMI	23 ± 4
Smoking status: n (%)	
- Current smokers	69 (15%)
- Ex-smokers	41 (9%)
- Never smokers	340 (76%)
Job title	
Wood Supply – pre-processing (front end)	39 (9%)
- Forestry (forest concession manager, technician, head forest, manager, supervisor, controller, grower)	10 (2%)
- Wood logs factory (wood log scaler, wood marker, logs cutter, valuer)	12 (3%)
- Wood loading	4 (1%)
- Wood seasoning (greenhouse)	3 (1%)
- Wood treatment	5 (1%)
- Chainsaw worker	5(1%)
Wood processing	288 (64%)
- Sawyer/helper/supervisor	32 (7%)
- Machine operator/helper/drilling/cutting time controller	84 (19%)
- Carving	4 (1%)
- Planing	4 (1%)
- Sanding	18 (4%)
- Assembling/Skeleton maker	125 (28%)
- Upholstering	4 (1%)
- Painting/varnishing	17 (4%)
Post processing (back end)	123 (27%)
- Office (office worker, HR manager/assistant, billing work, intern	19 (4%)
- Locksmith workshop/iron bending	20 (4%)
- Maintenance (electrician, mechanical, saw sharpener)	20 (4%)
- Security	14 (3%)
- Wood yard sale (Wood seller, seller, sales promotor)	5 (1%)
- Warehouse faithful/arranger	7 (2%)
- Supervision (head Production, general supervisor)	5 (1%)
- Kitchen (cook)	4 (1%)
- Cleaner (cleaner, road clearer)	10 (2%)
- Driver (driver, helper)	19 (4%)
Total years in industry	8.6 ± 8.2
Total years in the current job	7.3 ± 7.6
Past history of lung disease (self-reported)	
Previous treatment for tuberculosis	27 (6%)
Repeated childhood chest infections	17 (4%)
Previous treatment for chronic bronchitis	4 (1%)
Family history of allergy	157 (35%)
Presence of atopy (positive Phadiotop test/family history of allergy)	217 (48%)

Table 5.3: Current job exposure characteristics of wood processing workers in Mozambique

Job characteristic	Prevalence (%) n = 450
Types of wood used	
- African teak *(Pterocarpus angolensis DC)*	338 (75%)
- Mahogany bean *(Afzelia quanzensis Welw)*	337 (75%)
- Panga-panga *(Millettia Stuhlmannii Taub)*	248 (55%)
- Pine *(Pinussp)*	189 (42%)
- Missanda *(Erythrophleum suaveolens Brenan)*	129 (29%)
- Lebombo ironwood *(Androstacys johnsonii Prain)*	126 (28%)
- African mahogany *(Khaya nyasica Stapf)*	98 (22%)
- Mutondo *(Cordyla Africana)*	68 (15%)
- African sandalwood *(Spirostachys AfricanaSonder)*	35 (8%)
- Zebrawood *(Microberliniabrazzavillensis)*	14 (3%)
- Other (e.g. Messassa, Ncula, Mipepe) *(Brachystegiaspiciformis, Pterocarpustinctorious, Albiziaadianthifolia)*	77 (17%)
Chemicals used during wood processing	
- Glues	160 (36%)
- Varnishes	103 (23%)
- Hardeners	37 (8%)
- Dyes	33 (7%)
- Solvents	33 (7%)
- Other (e.g. ink, motor oil, fuel, wax, paraffin)	35 (8%)
Level of dust produced in current job	
- None	41 (9%)
- A little	108 (24%)
- An average amount	96 (21%)
- A lot	205 (46%)
Distance from source of exposure	
- Right next to the source (<1 meter)	236 (52%)
- About 1-2 meters away	94 (21%)
- More than 3 meters away	82 (18%)
- Not applicable	38 (8%)
Regular (daily use) of personal protective equipment	
- PPE used during work shift	382 (89%)
- Masks	326 (85%)
- Goggles	187 (42%)
- Gloves	155 (41%)
- Aprons	34 (9%)
- Other	254 (56%)

Table 5.4: Asthma history and respiratory symptoms reported by wood processing workers in Mozambique

Symptom	Prevalence (%) n=450
Asthma history	
Ever asthma	48 (11%)
Doctor-diagnosed asthma	28 (6%)
- ≤ 16 years	23 (5%)
- > 16 years	5 (1%)
Current use of asthma medication	6 (1%)
Asthma attack in the past 12 months	8 (2%)
Current use of asthma medication OR Asthma attack in the past 12 months	9 (2%)
Asthma-related symptoms	
Ever attacks of wheezing (wheezing in the past)	66 (15%)
Wheezing in the past 12 months	29 (6%)
Shortness of breath while wheezing in the last 12 months	11 (2%)
Woken up with chest tightness in the last 12 months	63 (15%)
Attack of shortness of breath at rest during daytime in the last 12 months	34 (8%)
Attack of shortness of breath following running or exercise in the last 12 months	58 (13%)
Woken up by an attack of shortness of breath in the last 12 months	27 (6%)
More symptomatic (≥ 2 asthma-related symptoms)	45 (10%)
Less symptomatic (0 – 1 asthma-related symptom)	405 (90%)
Asthma symptom score*	
0	320 (71%)
1	85 (19%)
2	33 (7%)
3	8 (2%)
4	2 (0.4%)
5	2 (0.4%)
Upper airway symptoms	
Presence of ocular-nasal symptoms ever	153 (34%)

*Asthma symptom score: An asthma symptom score was computed based on the sum of answers (0=no, 1=yes) to five questions on asthma-like symptoms in the past 12 months (short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath)

5.3.4 Work-related symptoms

While work-related ocular-nasal symptoms were reported by 40% of workers, a much lower proportion (14%) reported work-related chest symptoms. However, only 8% reported that their chest symptoms improved when away from work (Table 5.5). A very small proportion (2%) reported job changes prompted by work-related chest symptoms. Wood dust exposure was reported to be the main causal factor for both chest symptoms (12%) as well as ocular-nasal symptoms (36%). A small proportion (1%) of workers reported their symptoms being associated with episodes of high exposure to wood dust.

Table 5.5: Work-related symptoms reported by wood processing workers in Mozambique

Symptom	Prevalence (%) n = 450
Work-related asthma symptoms	
Episode of high exposure at work causing tight chest, shortness of breath, wheeze or cough	3 (1%)
Work-related chest symptoms (ever) [a]	65 (14%)
Work-related chest symptoms [b]	36 (8%)
Job change due to work-related chest symptoms	7 (2%)
Causes of chest symptoms	58 (13%)
- Wood dust	53 (12%)
- Other (Machinery, heavy lifting, varnish)	5 (1%)
Work-related upper airway symptoms	
Work-related ocular-nasal symptoms (ever) [a]	182 (40%)
Work-related ocular-nasal symptoms [b]	88 (20%)
Causes of ocular-nasal symptoms	173 (38%)
Wood dust	164 (36%)
Other (smoke, varnish, glue)	9 (2%)

[a] Symptoms (chest / ocular-nasal) experienced at work ever
[b] Symptoms (chest / ocular-nasal) experienced at work that improves when away from work

5.3.5 Spirometry quality grades

Spirometry quality was assessed using Easyone and ATS (2019) grades as outlined in Table 5.6. The quality grades obtained using the ATS/ERS (2019) grading system compared favorably with the Easyone grading system, the former producing a slightly lower proportion of unacceptable and unusable tests (grade F).

Table 5.6: Spirometry quality grades of wood processing workers in Mozambique

	Pre-BD Easyone grade n (%)	**Pre-BD ATS/ERS Grade (2019)** n (%)	**Post-BD Easyone grade** n (%)	**Post-BD ATS/ERS Grade (2019)** n (%)
A	160 (36)	228 (51)	178 (41)	243 (56)
B	67 (15)	66 (15)	65 (15)	49 (11)
C	96 (22)	31 (7)	76 (18)	28 (6)
D	108 (24)	11 (2)	87 (20)	11 (3)
E	-	95 (21)	-	75 (17)
U	-	4 (1)	-	17 (4)
F	12 (3)	8 (2)	25 (6)	8 (2)
Total	443	443	431	431

Pre-BD: pre-bronchodilator; post-BD: post-bronchodilator

5.3.6 Pulmonary lung function indices

The results of pulmonary function, bronchial reversibility and fractional exhaled nitric oxide tests are presented in Table 5.7. Using the Global lung function initiative (GLI-2012) reference values, there were 26% of workers had an FEV_1 of <80% predicted and 25% with FEV_1/FVC < LLN. A lower proportion (19%) had evidence of airflow obstruction, with (14%) having fixed airflow obstruction, defined as a post-bronchodilator FEV_1/FVC ratio <70%. On the other hand, the prevalence of bronchial reversibility measured using two different definitions was between 3-6%. The kappa statistic demonstrated substantial agreement between the two indices of reversibility (K=0.62, p<0.001).

The median FeNO levels in this study population were 18.5 ppb (interquartile range: 12 – 27), with 23% having elevated (25–50 ppb) levels and 5% having high (>50 ppb) levels suggestive of airway inflammation.

Table 5.7: Pulmonary function induces of wood processing workers in Mozambique

Pulmonary function indices * #	Prevalence (%) n=435
FEV_1 L [median (IQR)]	3.03 (2.59 – 3.44)
FVC L [median (IQR)]	3.80 (3.36 – 4.39)
FEV_1 % pred. [median (IQR)]	89 (79 – 96)
FVC % pred. [median (IQR)]	92 (84 – 104)
FEV_1< LLN	102 (23%)
FEV_1< 80% pred.	115 (26%)
FVC < LLN	89 (20%)
FVC < 80% pred.	78 (18%)
FEV_1 /FVC [median (IQR)]	80 (73 – 86)
FEV_1 /FVC < LLN	107 (25%)
FEV_1 /FVC < 70% (pre-bronchodilator)	83 (19%)
Fixed airway obstruction	**n = 423**
Post-bronchodilator: FEV_1 /FVC < 70%	58 (14%)
Bronchial reversibility (PBD)**	**n = 423**
≥200 ml FEV_1 increase post-bronchodilator	71 (17%)
≥12% FEV_1 increase post-bronchodilator	14 (3%)
≥12% and ≥200 ml FEV_1 increase post-bronchodilator	14 (3%)
Post-bronchodilator ΔFEV_1% ⩾9% of predicted FEV_1	24 (6%)
Fractional exhaled nitric oxide (FeNO)	**n = 443**
FeNO (ppb) [median (IQR)]	18.5 (12 – 27)
Low <25 ppb	317 (72%)
Elevated 25 – 50 ppb	104 (23%)
High >50 ppb	22 (5%)

FEV_1: forced expiratory volume in 1 second; FVC: forced vital capacity; L: litres; LLN: Lower limit of normal;
IQR: interquartile range; % pred: % predicted; *: pre-bronchodilator values, unless stated otherwise;
#:Global lung function initiative (GLI) reference values used;
Airway reversibility:≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD ΔFEV_1% ⩾9% of the predicted FEV_1
NOTE: All workers with an ATS grade of "F" were removed from the baseline and bronchial reversibility analysis

5.3.7 Prevalence of asthma phenotypes

Among the asthma phenotypes identifiable, the prevalence of current asthma (7%) was much higher than work-related asthma (2%) (Table 5.8). The prevalence of atopic asthma was 4% and non-atopic asthma 3%. Of note, the proportion of work-related asthma were equally distributed (2%) in atopics and non-atopics.

Table 5.8: Prevalence of asthma phenotypes among wood processing workers in Mozambique

Asthma phenotypes	
Current asthma	33 (7%)
Atopic asthma	18 (4%)
Non-atopic asthma	15 (3%)
Work-related asthma	10 (2%)

Current asthma: having an asthma attack in the past 12 months, or current use of asthma medication or waking up with an attack of shortness of breath in the past 12 months.
Atopic asthma: *current asthma* and presence of atopy. *Nonatopic asthma*: *current asthma* and nonatopic.
*Work-related asthma: current asthma and w*ork-related chest symptoms;

5.3.8 Association between continuous indices of bronchial reversibility and FeNO

In the correlational analysis, there was a statistically significant weak negative correlation between all three continuous indices of bronchialreversibilityand FeNO (Table 5.9). On the other hand, there was a weak positive correlation between continuous indices of bronchial reversibilityand FeNO, when the latter was stratified for levels ≥25 ppb, and even more so for levels of FeNO ≥50 ppb. However, less than 1% of the variability in bronchial reversibility could be explained by the FeNO levels.

Table 5.9: Association between continuous indices of bronchial reversibility and FeNO among wood processing workers in Mozambique

	FeNO			
	FeNO, ppb $^{\#}$		**FeNO ≥25 ppb**	**FeNO ≥50 ppb**
	Beta coefficient (95% CI)	**R^2**	**Odds ratio (95% CI)**	
Absolute FEV_1 change	-0.01 (-0.09 – -0.06)	<0.01	0.97 (0.72 – 1.31)	1.17 (0.65 – 2.12)
FEV_1 % of the initial FEV_1	-0.02 (-0.10 – -0.06)	<0.01	0.94 (0.70 – 1.27)	1.16 (0.66 – 2.05)
FEV_1 % predicted	-0.02 (-0.10 -0.06)	<0.01	0.96 (0.71 – 1.30)	1.13 (0.63 – 2.04)

Each odds ratio/Beta coefficient represents a separate unadjusted regression model; CI: Confidence Interval;
$^{\#}$: natural log-transformed values;*: p-value < 0.05; **: p-value < 0.01

5.4 DISCUSSION

This is the first study to characterise various asthma phenotypes in wood processing workers using a repertoire of asthma indices that included symptoms, bronchial reversibility and exhaled nitric oxide levels. Using standardized ECRHS asthma questions, the prevalence of current asthma was 7%, with equal proportions of atopic and non-atopic asthma (4%) being present. Given that asthma symptom scores (ASS) can be useful in identifying asthma cases in epidemiological studies instead of dichotomous definitions of asthma (22)(30)(31), there were 10% of workers with an ASS ≥ 2, being the more symptomatic. Using lung function indices, significant bronchial reversibility was present in 3-6% of workers, while 5% had high FeNO levels (>50 ppb) suggestive of airway inflammation. Furthermore, FeNO is also an important sub-clinical marker for identification of individuals with asthma. All these estimates obtained using difference indices are relatively consistent with each other. To the best of our knowledge, this is the first Mozambiquan study to report on the prevalence of adult asthma in general, while 2% of wood processing workers were found to have work-related asthma. Overall, the figures for asthma are on the upper end of the range reported for woodworkers in other African countries (3-7%), but on the lower end of the range reported for countries beyond the continent (6-18%) (8).

Workers in this current study had an average employment duration of nine years in their current wood processing factory. Furthermore, almost half the workforce reported that their current job produced a lot of wood dust in their subjective assessment since they worked close to the source of dust production. These occupational characteristics are very similar to that reported in other African settings among wood workers with respiratory symptoms suggestive of asthma. The employment duration reported in this current study is within the range of 4-12.5 years reported in other settings in Africa (10,11, 12, 13,32). Interestingly, this is almost half the period reported in other international studies beyond the continent, in which the employment duration ranged between 8-19 years (6, 19,21,33). This probably suggests that African wood processing workers have probably higher wood dust exposures due to poor working conditions and control measures. This was evident from the exposure characterization study of workers conducted in the current study (chapter 4), which demonstrated elevated mean wood dust exposures (3.29 mg/m^3), as well as in Tanzanian (3.86 mg/m^3) (11), Ethiopian (4.66 mg/m^3) (34), South African (5.11 mg/m^3) (10) wood workers, such that they develop symptoms over a shorter period. In contrast with high exposure levels found in African studies, the exposure levels found in British

(1.9 mg/m^3) (19), Australian (1.72 mg/m^3 in dry mill and 1.52 mg/m^3) in green mill (5), Norwegian (0.72 mg/m^3) (35), Danish (0.58 mg/m^3) (36) or other European studies were much lower. However, a healthy worker effect cannot be totally excluded.

In the current study, 34% of subjects reported presence of general ocular-nasal symptoms. These findings are similar to the study reported from Cameroon (30%) (17), but lower than Nigerian (78%) (14) and South African wood workers (49%) (9). Such wide variation in prevalences was also found in other international studies, where the prevalence was similar to those reported by Malinowski et al. (33%), (37) Arbak et al. (34%), (38) although lower figures were reported by Schlünssen et al. (19%), (39), Publio (16%), (7) and Wiggans et al. (13%), (19). These differences could be attributed to a number of factors including the type of woods processed (having degrees of irritancy or allergencity), the actual wood dust levels and the duration of exposure to the wood dust particulates and associated bioaerosol as well as chemical exposures (varnishes, glues) associated with treating the woods prior to processing.

As to be expected the prevalence of work-related lower respiratory symptoms were much lower than work-related ocular-nasal symptoms. There were 14% of workers reported ever experiencing work-related chest symptoms, and at least 8% reported their chest symptoms improving when away from work, which is a better marker of work-relatedness. These results are in keeping with the findings of other studies reported by higher than reported by Publio (6%), (7) Schlünssen et al. (9%), (40) Wiggans at al. (11%), (19) and Jacobsen et al. (14%),(41). Wood dust exposure was reported to be a main cause of both chest symptoms (12%) and ocular-nasal symptoms (36%), more so the latter suggesting probably a major irritative component attributable to the high wood dust particulate exposures (GM = 3.29 mg/m^3), which are likely to settle in the upper airways, as has been reported in the exposure assessment component of the overall study.

While the overall prevalence of airflow obstruction in this study was 19%, one third (6%) among these workers had bronchial reversibility suggestive of asthma, while the remaining two thirds had evidence of fixed airway obstruction suggestive of chronic obstructive pulmonary disease (COPD). Unfortunately, there does not appear to be any Mozambiquan studies of adult asthma and COPD reported in the literature that could be used for comparative purposes. However, the findings of this study are similar to those reported by Fentie et al. (42) among Ethiopian workers (17%). However, earlier studies in South Africa have reported much higher prevalences (30%)

(9) compared to studies from Cameroon (6%) (17) and other European countries (6%)(41). As has been reported in this study, there was a relatively low prevalence of current or ex-smokers (24%) and only 12 workers with fixed airway obstruction (n=58) being current smokers, suggesting that smoking did not feature as a prominent cause of obstructive lung disease. Furthermore, among those with fixed airway obstruction only 6 workers had a previous history of TB, suggesting that occupational as well as environmental exposures (biomass fuel, ambient particulates) are more likely to be contributing to the burden of obstructive lung disease in African populations (44).

There have been very few studies that have studied the inflammatory responses in exposed wood workers. To the best of our knowledge, this is the first African study to report high FeNO (>50 ppb) levels, in exposed wood workers with a prevalence of 5%. Other studies by Wiggans et al. (19) reported an 18% prevalence among British wood workers with FeNO >40 ppb. Almugally et al. (20) reported a mean FeNO of 32 ppb in Saudi Arabian workers compared to the 18.5 ppb observed in this study. Furthermore, there was a significant positive correlation between post-bronchodilator response and having FeNO ≥50 ppb, suggesting that workers with high FeNO were more likely to have significant airway reversibility as is present in asthma.Associations between FeNO and bronchial hyperresponsiveness have also been observed among South African health care workersas well as bakery, pastry and hairdresser apprentices (45, 46, 47). Taking the FeNO findings of this current study into account, this suggests that work-related asthma among these wood processing workers is likely to have both allergic and non-allergic components, associated with airway inflammation, and merits further investigation to better understand underlying pathophysiologic mechanisms (48).

This study has been an important contribution in better understanding the epidemiology of wood processing workers in Mozambique. It strengths lie in the fact that it used objective markers such as spirometry with bronchial reversibility and FeNO to assess the presence of asthma. Furthermore, the bronchodilator response was statistically analysed using two approaches to obtain a better range of potential responses, since traditional approaches may underestimate its presence (27). To the best of our knowledge, this is the first epidemiological study to assess the prevalence of asthma and rhinitis among workers exposed to wood dust in Mozambique. Furthermore, the use of exhaled nitric oxide levels to study airway inflammation is also a novel component of the study.

Despite these strengths, there are some limitations regarding to study design and possible selection bias. The cross-sectional nature of this study did not allow more detailed investigations to establish the temporality between exposure and outcomes. There is also a possibility that there may have been a healthy worker effect, which may have underestimated the disease burden in this group of workers since the health outcome status of non-respondents was not known. Furthermore, the possibility of sampling bias affecting the results cannot be completely excluded, although it is unlikely due to the very high (88%) response rate.

5.5 CONCLUSION

This study has demonstrated that workers in the Mozambique wood processing industry experience a high proportion of work-related chest and ocular-nasal symptoms, which can be attributable to exposure to wood dust and other chemical exposures encountered in the wood processing. The study has also shown that the prevalence of asthma among wood workers in Mozambique is on the upper end of the range of estimates reported for other African countries. Both allergic and non-allergic asthma phenotypes were prevalent in similar proportions. A better understanding of the allergic and non-allergic components of the asthma in wood workers in relation to host and environmental risk factors may lead to the development of improved preventive approaches to reduce the burden of obstructive lung disease in this working population.

5.6 REFERENCES

1. Fentie D, Mariam TG, Mulat E, Reta W. Assessment of respiratory symptoms among woodworkers in Jimma Town, Southwest Ethiopia, A comparative cross-sectional study. Biomed J Sci & Tech Res. 2019; 18(2):13425-30.
2. Wiggans RE, Evans G, Fishwick D, Barber CM. Asthma in furniture and wood processing workers: A systematic review. Occupational Medicine. 2016, 66 (3):193–201.
3. Pérez-Ríos M, Ruano-Ravina A, Etminan M, Takkouche B. A meta-analysis on wood dust exposure and risk of asthma. Allergy. 2010;65(4):467–73.
4. Alwis KU. Occupational exposure to wood dust. The university of Sydney; 1998.
5. Mandryk J, Alwis KU, Hocking AD. Effects of Personal Exposures on Pulmonary Function and Work-related Symptoms Among Sawmill Workers. Ann Occup Hyg. 2000;44(4):281–9.
6. Douwes J, McLean D, Slater T, Pearce N. Asthma and other respiratory symptoms in New Zealand pine processing sawmill workers. Am J Ind Med. 2001 Jun;39(6):608–15.
7. Publio A. Prevalence of respiratory symptoms among furniture factory workers, in Votuporanga-SP. Campinas, SP . 2008.
8. Chamba P, Nunes E. Work-related asthma among workers in the wood-processing industry : A review. Curr Allergy Clin Immunol. 2016;29(2):110–7.
9. Shamssain MH. Pulmonary function and symptoms in workers exposed to wood dust. Thorax. 1992;47(2):84–7.
10. Fox FH. An Epidemiological Survey of Asthma in a Pine Sawmill in South Africa. 2004.
11. Rongo LMB, Besselink A, Msamanga GI, Dolmans WM V, Demers PA, Heederik D. Respiratory Symptoms and Dust Exposure Among Male Workers in Small-Scale Wood Industries in Tanzania. J Occup Environ Med. 2002;44(12):1153–60.
12. Asgedom AA, Bråtveit M, Moen BE. High prevalence of respiratory symptoms among particleboard workers in ethiopia: A cross-sectional study. Int J Environ Res Public Health. 2019;16(12):10.
13. Ugheoke AJ, Ebomoyi MI, Iyawe VI. Influence of smoking on respiratory symptoms and lung function indices in sawmill workers in Benin City, Nigeria. Niger J Physiol Sci 2006;21(1–2):49–54.
14. Aguwa EN, Okeke TA , Asuzu MC. The prevalence of occupational asthma and rhinitis among woodworkers in south-eastern Nigeria. Tanzan Health Res Bull. 2007;9(1):52–5.
15. Tobin et al. Occupational Exposure to Wood Dust and Respiratory Health Status of

Sawmill Workers in South-South Nigeria. Pollut Eff Control. 2016;4(1):4–9.

16. Mumuni M. Respiratory Health Problems Among Sawmill Workers At the Timber Market , Accra. University of Ghana; 2015.
17. Nde F, Mbatchou H, Nebo J, Djomo A, Tsafack P and Brouwer C. Respiratory Symptoms and Pulmonary Function tests among Informal Sector Workers Exposed to Wood Dust in Douala, Cameroon. J Allergy Ther. 2015;06(06):8–11.
18. Jacobsen G, Schaumburg I, Sigsgaard T. Non-malignant respiratory diseases and occupational exposure to wood dust. Part I. Fresh wood and mixed wood industry. Ann Agric Environ Med. 2010;17:15–28.
19. Wiggans RE, Sumner J, Robinson E. Respiratory symptoms, lung function and sensitisation across different exposure groups of British woodworkers. Thorax. 2017;72(3):A1-278.
20. Almugally O , Alhaiti A, Aldwsari A, et al. Pulmonary function tests and exhaled nitric oxide and human serum albumin among wood dust workers in Saudi Arabia. Respir Ther Progr. 2(6):1(Poster).
21. Paraskevaidou K, Porpodis K, Kontakiotis T, Kioumis I, Spyratos D, Papakosta D. Asthma and rhinitis in Greek furniture workers. J Asthma. 2019;1–10.
22. Pekkanen J, Sunyer J, Anto JM, Burney P. Operational definitions of asthma in studies on its aetiology. Eur Respir J. 2005;26(1):28–35.
23. Le Moual N, Varraso R, Siroux V, Dumas O, Nadif R, Pin I, et al. Domestic use of cleaning sprays and asthma activity in females. Eur Respir J. 2012;40(6):1381–9.
24. Miller MR, Crapo R, Hankinson J, Brusasco V, Burgos F, Casaburi R, et al. General considerations for lung function testing. Eur Respir J. 2005;26(1):153–61.
25. Graham BL, Steenbruggen I, Barjaktarevic IZ, Cooper BG, Hall GL, Hallstrand TS, et al. Standardization of spirometry 2019 update an official American Thoracic Society and European Respiratory Society technical statement. American Journal of Respiratory and Critical Care Medicine. 2019. 200 (8): E70–88.
26. American Thoracic Society. Lung function testing: selection of reference values and interpretative strategies. Am Rev Respir Dis. 1991;144(5):1202–18.
27. Tuomisto LE, Ilmarinen P, Lehtimäki L, Tommola M, Kankaanranta H. Immediate bronchodilator response in FEV 1 as a diagnostic criterion for adult asthma. Eur Respir J. 2019;53(2):1–7.
28. ATS and ERS. ATS/ERS recommendations for standardized procedures for the online and offline measurement of exhaled lower respiratory nitric oxide and nasal nitric oxide,

2005. Am J Respir Crit Care Med. 2005;171(8):912–30.

29. Bjermer L, Alving K, Diamant Z, Magnussen H, Pavord I, Piacentini G, et al. Current evidence and future research needs for FeNO measurement in respiratory diseases. Respir Med. 2014;108(6):830–41.

30. Sunyer J, Pekkanen J, Svanes C, Janson C, Marco R De, Burney P. Asthma score : predictive ability and risk factors. Allergy. 2007;62:142–8.

31. Sá-Sousa A, Pereira AM, Almeida R, Araújo L, Couto M, Jacinto T, et al. Adult Asthma Scores—Development and Validation of Multivariable Scores to Identify Asthma in Surveys. J Allergy Clin Immunol Pract. 2019;7(1):183-190.e6.

32. Ugheoke A, Wahab KW and Erhabor GE . Prevalence of respiratory symptoms among sawmill workers in Benin City, Nigeria. Int J Trop Med. 2009;4(1):1–3.

33. Talini D, Monteverdi A, Benvenuti A, Petrozzino M, Di Pede F, Lemmi M, et al. Asthma-like symptoms, atopy, and bronchial responsiveness in furniture workers. Occup Environ Med. 1998;55(11):786–91.

34. Asgedom A, Bråtveit M, Schlünssen V , Moen EB. Exposure to inhalable dust, endotoxin and formaldehyde in factories processing particleboards from eucalyptus trees in Ethiopia. Env Occup Heal Pract. 2020;1–10.

35. Straumfors A, Olsen R, Daae HL, Afanou A, McLean D, Corbin M, et al. Exposure to Wood Dust, Microbial Components, and Terpenes in the Norwegian Sawmill Industry. Ann Work Expo Heal. 2018;20(20):1–15.

36. Hagström K, Jacobsen G, Sigsgaard T, Schaumburg I, Erlandsen M, Schlunssen V. Predictors of monoterpene exposure in the Danish furniture industry. Ann Occup Hyg. 2012 ;56(3):253–63.

37. Milanowski J, Góra A, Skorska C, et al. Work-related symptoms among furniture factory workers in Lublin Region (Eastern Poland). Ann Agric Environ Med. 2002;9:99–103.

38. Arbak P, Bilgin C, Balbay O, Yesildal N, Annakhhaya AN, Ulger F. Respiratory Symptoms and Peak Expiratory Flow Rates Among Furniture - Decoration Students. Ann Agric Env Med. 2004;(11):13–7.

39. Schlünssen V, Schaumburg I, Taudorf E, Mikkelsen AB, Sigsgaard T. Respiratory symptoms and lung function among Danish woodworkers. J Occup Environ Med. 2002;44(1):82–98.

40. Schlünssen V, Kespohl S, Jacobsen G, Raulf-Heimsoth M, Schaumburg I, Sigsgaard T. Immunoglobulin E-mediated sensitization to pine and beech dust in relation to wood dust exposure levels and respiratory symptoms in the furniture industry. Scand J Work Environ

Heal. 2011;37(2):159–67.

41. Jacobsen G, Schlünssen V, Schaumburg I, Sigsgaard T. Increased incidence of respiratory symptoms among female woodworkers exposed to dry wood. Eur Respir J. 2009;33(6):1268–76.
42. Fentie D, Mariam TG, Mulat E, Demissie WR. Prevalence of Respiratory Disorders among Woodworkers in Jimma Town, Southwest Ethiopia. Pulm Med Respir Res. 2019;5(1):1–6.
43. Jacobsen G, Schlünssen V, Schaumburg I, Taudorf E, Sigsgaard T. Longitudinal lung function decline and wood dust exposure in the furniture industry. Eur Respir J. 2008;31(2):334–42.
44. Jones R. The scale of the problem of obstructive lung disease in Africa becomes clearer, but where are the solutions? Eur Respir J. 2018;51(2):1702562.
45. Mwanga H. Risk factors for work-related asthma in health care workers with exposure to diverse cleaning agents. University of Cape Town. 2019.
46. Baatjies R, Jeebhay MF. Sensitisation to cereal flour allergens is a major determinant of elevated exhaled nitric oxide in bakers. Occup Environ Med. 2013;70(5):310–6
47. Tossa P, Paris C, Zmirou-Navier D, Demange V, Acouetey DS, Michaely JP, et al. Increase in exhaled nitric oxide is associated with bronchial hyperresponsiveness among apprentices. Am J Respir Crit Care Med. 2010;182(6):738–44.
48. Schluenssen V, Sigsgaard T, Raulf-Heimsoth M, Kespohl S. Workplace exposure to wood dust and the prevalence of wood-specific sensitization. Allergologie. 2012;35(8):402–12.

CHAPTER 6

HOST AND ENVIRONMENTAL RISK FACTORS ASSOCIATED WITH VARIOUS ASTHMA-RELATED OUTCOMES AMONG WORKERS IN THE MOZAMBIQUAN WOOD PROCESSING INDUSTRY

ABSTRACT

Background: Various studies have partially examined the role of individual host and environmental risk factors in rhinitis and asthma among wood processing workers, with a view to better understanding the underlying causative mechanisms in order to develop improved preventive strategies to reduce the disease burden. The aim of this study was to determine host and self-reported environmental risk factors associated with work-related respiratory symptoms (upper and lower), airway reversibility and underlying inflammation among wood processing workers in Mozambique.

Methods: A cross-sectional study of 450 wood processing workers was conducted in three provinces of Mozambique. Each worker completed a modified European Community Respiratory Health Survey (ECRHS) questionnaire. A total of 431 workers successfully performed pre and post-bronchodilator spirometry, while 443 workers had FeNO measurements done prior to spirometry. Sera from 391 participants was collected and analyzed for reactivity to common aero-allergens (Phadiatop). An asthma symptom score was computed based on the sum of responses to five questions reported in the past 12 months. The clinical outcomes assessed included work-related ocular–nasal (WRONS) and asthma (WRAS) symptoms that were experienced in the past or in the last 12 months. Airway obstruction was defined as baseline FEV_1 /FVC < 70% while bronchial reversibility was defined in two ways, a ≥12% and ≥200 ml FEV_1 increase post-bronchodilator and or a ≥9% FEV_1 increase post-bronchodilator as a proportion of the FEV_1 % predicted. High FeNO levels were defined as those ≥50 ppb, suggesting the presence of airway inflammation.

Results: The analysis of individual host-related factors, revealed that workers with a history of work-related ocular nasal symptoms (WRONS) were more likely to be atopic (OR= 2.04, 95% CI: 1.20 – 3.47) and female (OR= 2.63, 95% CI: 1.23 – 5.88). Workers with significant bronchial reversibility were more likely to be of increasing age (OR= 1.06, 95% CI: 1.02 – 1.10). Workers that were male (OR= 1.33, 95% CI: 1.05 – 1.69) and atopic (OR= 1.16, 95% CI: 1.03– 1.31) were more likely to have higher FeNO, while lower levels were more likely in smokers. In the multivariate models, adjusted for confounders (age, gender, atopy and smoking), the most important environmental factors identified were level of exposure, wood species processed and workplace cleaning practices. An exposure-response relationship was observed between a history of WRONS and belonging to the medium exposure group (OR= 3.33, 95% CI: 0.93 – 11.91) comprising machine operators, painter-varnishers and assemblers, and those belonging to the high exposure group comprising planers, sanders, sawyers and carvers (OR= 4.11, 95%

CI: 1.03 – 16.37). While working with Mutondo wood species was independently associated with both work-related ocular nasal symptoms (OR= 6.93, 95% CI 3.76 – 12.77) and work-related asthma symptoms (OR= 2.32, 95% CI: 1.24 – 4.34), working with Missanda (OR= 5.74, 95% CI: 3.67 – 8.98), Panga-panga (OR= 2.12 95% CI: 1.43 – 3.12) and mahogany bean (OR= 1.82, 95% CI: 1.15 – 2.87) species were associated with only work-related ocular nasal symptoms. Furthermore, workers reporting cleaning equipment were less likely to have a high (≥2) asthma symptom score (OR= 0.29, 95% CI: 0.10 – 0.83).

Conclusion: This study has demonstrated that the main individual host factors associated with work-related ocular-nasal and asthma symptoms were age, male gender, and atopy. Exposure to Mutondo (Cordyla Africana) wood species was associated with work-related ocular-nasal and asthma symptoms, whileMissanda (*Erythrophleum suaveolens Brenan*), Panga-panga (*Millettia Stuhlmannii Taub*) and Mahogany bean (*Afzelia quanzensis Welw.*) woods were associated mainly with work-related ocular nasal symptoms.

6.1 INTRODUCTION

Various studies have partially examined the role of individual host and environmental risk factors in rhinitis and asthma among wood processing workers. In a meta-analysis of wood dust exposure and the risk of work-related asthma by Perez-Rios et al. (1), aside from confirming the increased risk asthma among wood workers, it also highlighted the possible role of genetic factors in that Caucasian populations appeared to have a higher risk than Asian populations. Danish and Italian studies of woodworkers have demonstrated that atopy is an important modifier of the association observed between asthma and exposure to wood dust (2, 3). Furthermore, there is also evidence to suggest that occupational rhino-conjunctivitis, which often precedes the onset of IgE-mediated occupational asthma, could also be considered an important risk factor for future development of occupational asthma (4, 5). While the relationship between smoking and occupational asthma is complex and often contradictory, some studies have demonstrated that sawmill workers that smoked were at increased risk of developing respiratory problems (6, 7, 8, 9) . The study by Bolund et al., (10) suggested that women wood dust-exposed workers were at increased risk for developing new-onset COPD and decline in lung function.

Other studies of wood workers have evaluated the role of various environmental risk factors in wood processing workers and shown that exposure duration, exposure concentration as well as exposure to chemicals are associated with an increased prevalence of adverse upper and lower respiratory health effects, including rhinitis and asthma.

Aguwa et al. (6) found that Nigerian workers with more than 10 years of exposure had a higher prevalence of rhinitis (36.5%) and asthma (6.5%) compared to those with less than 2 years exposure, having prevalences of 8.7% for rhinitis and 1.9% for asthma. The study by Meo (11) in small scale wood industries reported a negative association between peak expiratory flow (PEF) and duration of exposure. Workers with an exposure duration greater than 8 years had a much lower PEF (177.00 ± 22.29 liters/min) compared to those with less than 4 years (PEF: 312.28 ± 23.62 liters/min). In a South African study of wood workers (12), the prevalence of cough was much higher (66%) among those with a 9-12 year duration of employment than those with 1-4 years (35%). A similar pattern was observed for nasal symptoms (55% versus 49%). The study also found that the proportion of workers with airway obstruction ($FEV_1/FVC <$ 70%) was twice as high (56%) for employment duration >10 years compared to <10 years

(27%). Furthermore, Mumuni (13) have reported that Ghanaian sawmill workers employed for greater than ten years were more likely to develop cough (OR= 1.95; 95% CI: 1.28 - 2.98), produce phlegm (OR= 1.77; 95% CI: 1.16 - 2.69), have shortness of breath (OR= 1.31; 95% CI: 0.91 - 1.90) and experience wheeze (OR= 1.07; 95% CI: 0.75 - 1.53). A similar finding has been reported in Iranian wood workers with more than 15 years of exposure (9).

With regard to wood dust exposure concentrations, Schlünssen et al. (2) demonstrated that symptomatic bronchial hyperresponsiveness was related to wood dust in a dose dependent manner (OR= 18.3; CI: 2.0–170.8) when comparing the group with the highest (4.10 mg/m^3) and lowest (0.17 mg/m^3) exposures. The same trend was observed for work-related asthma symptoms (OR= 6.4; CI: 1.6–26.4). Allergic symptoms among Tanzanian workers in small-scale wood industries were more commonly reported in the highly exposed group (OR= 2.7; CI: 95% CI= 1.8–4.0) compared to controls (14). Lytras et al.(15), also demonstrated that the incidence of COPD increased with increasing of level of exposure in the ECRHS study of occupational exposures over a 20-year period.

Other important environmental risk factors for occupational asthma and rhinitis in wood processing workers include exposure to chemicals. Among furniture workers, Talini et al. (3) demonstrated that the prevalence of either attacks of shortness of breath with wheeze or dyspnoea was the highest in spray painters exposed to solvents and diisocyanate vapours (13.5% and 11.5%) respectively, followed by woodworkers (7.7% and 6.3%) and assemblers (1.6% and 1.6%). Paraskevaidou et al.(16) also found that asthma (23%) and rhinitis (26%) were more frequently observed in the chemically exposed group (exposed to glues and paint) of furniture makers compared to those mainly involved with wood, having asthma (9%) and rhinitis (17%).

There have been relatively few studies that have conducted a comprehensive assessment of both individual host and environmental health factors. Furthermore, while there have been a number of isolated case reports reporting occupational asthma to individual wood species, to our knowledge, there have been no studies evaluating work-related respiratory symptoms, airway obstruction and inflammation, as well as rhinitis and asthma in relation to the specific exotic wood species commonly used in the Mozambiquan wood processing industry.

The aim of this study was to determine the host and self-reported environmental risk factors associated with work-related respiratory symptoms, airway obstruction, bronchial reversibility and exhaled nitric oxide (FeNO) among wood processing workers in Mozambique.

6.2 METHODS

6.2.1 Study design, population and sampling

A cross-sectional study of 450 workers was conducted in three major sites that included Maputo City where 142 furniture/joinery workers were employed in 12 factories, Maputo Province having 76 workers employed in 3 factories and Sofala Province with 232 furniture/joinery workers employed in 6 factories. Employers of selected factories were contacted prior to the recruitment and permission obtained to address the workers. Those who agreed to participate underwent the health outcome assessments that were conducted at the work site during work time. Ethics approval was obtained from the Human Research Ethics Committee (HREC) of the University of Cape Town (HREC Ref: 543/2016), National Bioethics Committee of Ministry of Health of Mozambique (40/CNBS/2015) and University of Michigan Medical School Institutional Review Board (HUM00070862).

6.2.2 Questionnaire

Each worker completed a standard interviewer-administered questionnaire of the European Community Respiratory Health Survey (ECRHS) for the investigation of asthma. The questionnaire was modified to include questions relating to current and previous employment, exposure to wood dust, types of wood the worker is exposed to, information regarding the origin of the wood species processed, as well as chemical and pesticide treatment of the woods. The questionnaire was translated into Portuguese and back translated to English to verify translation correctness. Interviews in Maputo City and Maputo Province were conducted by recently graduated physicians from Faculty of Medicine of Eduardo Mondlane University and in Sofala Province by a nurse and preventive medicine technician, all of whom received appropriate training prior to the study.

6.2.3 Test for atopy (Phadiatop)

There were 391 workers that successfully provided a blood sample. The blood sample (9 ml) was drawn using a Becton Dickinson Vacutainer SST tube (with gel medium and clot activator) bya qualified laboratory technologist. The blood was allowed to clot for 1-2 hours at room temperature (20-24 degrees Celsius) and then centrifuged at 1350 rpm for 10 minutes at room temperature prior to being stored at -70 degrees Celsius at the Laboratory of Central Hospital. These stored serum samples were then finally transported on dry ice to the University of Cape Town laboratories where they were all stored at minus 80 degrees Celsius prior to being couriered to the SANAS accredited (ISO 15189:2007), National Institute for Occupational Health (NIOH) Immunology laboratory for further analysis.

6.2.4 Spirometry and post-bronchodilator response (PBR)

Overall, there were 443 participants that performed pre-bronchodilator and 431 participants post-bronchodilator spirometry in this study. There were 12 workers whose spirometry outputs were graded as “F” according to the EasyOne spirometer.

Details of the spirometry method have been described earlier. In brief, the EasyOne spirometer was used according to the American Thoracic Society (ATS)/ERS guidelines for conducting spirometry (17).The timing of spirometry was during the working week. Special instructions to workers to ensure that tested individuals did not smoke tobacco (at least 2 hours before) nor did they take any anti-asthmatic inhalers (12 hours before) or oral asthma medications (48 hours before) prior to the test. The results of spirometry and BDR tests were recorded on lung function test data collection sheets and were graded for acceptability prior to being used in the statistical analysis.

6.2.5 Fractional Exhaled Nitric Oxide (FeNO)

A total of 443 workers underwent FeNO measurements using ATS/ERS recommendations for standardized procedures for the measurement of exhaled nitric oxide levels (18). A hand-held portable nitric oxide sampling device (NIOX MINO® Airway Inflammation Monitor (NIOX MINO); Aerocrine AB, Solna, Sweden) was used. The worker was seated comfortably, with the mouthpiece at the proper height and position. A nose clip was not used, as this may allow nasal NO to accumulate and promote leakage of this NO via the posterior nasopharynx. The worker inserted a mouthpiece and inhaled over 2 to 3 seconds through the mouth to total lung capacity (TLC), and then exhaled immediately, since breath holding could affect FeNO. Two technically adequate measurements were performed. If the measurements differed by 10 ppb or more, a third measurement was performed and the mean of all three measurements was used. The test was performed during the work shift prior to spirometry.

6.2.6 Operational definitions of host and environmental associated risk factors

Information regarding the host and environmental risk factors that could be considered in relation to work-related respiratory symptoms, airway obstruction, bronchial reversibility and FeNO was obtained from the modified ECRHS questionnaire, allergy tests (Phadiatop), spirometry with post-bronchodilator bronchial reversibility responses and FeNO measurements.

An *asthma symptom score* was computed based on the sum of answers (0=no, 1=yes) to five questions reported in the past 12 months. These included the presence of shortness of breath while wheezing; being woken up with chest tightness; an attack of shortness of breath at rest; an attack of shortness of breath after exercise; and being woken up by an attack of shortness of breath. A binary variable was created from these five asthma-related symptoms (≥ 2 symptoms vs 0-1 symptom). Having ≥ 2 asthma-related symptoms was considered ‘more symptomatic’ and 0-1 symptom as ‘less symptomatic’.

Work-related asthma symptoms and *work-related ocular–nasal symptoms* were defined as symptoms (chest/ocular-nasal) experienced at any time during their work. A more specific variable for both these outcomes was defined as symptoms (either chest/ocular-nasal) experienced at work that improved when away from work.

The presence of *atopy* was defined as sensitization to common aeroallergens (house dust mites, grass pollens, cat, dog, and cockroach) as determined by a positive Phadiatop® test (Phadia AB, Uppsala, Sweden), classified as any value ≥0.35ku/L.

Airway obstruction was defined as baseline $FEV_1/FVC < 70\%$, the *bronchial reversibility* was measured in two ways: i) as ≥12% and ≥200 ml FEV_1 increase post-bronchodilator and as ii) ≥9% FEV_1 increase post-bronchodilator as a proportion of FEV_1 % predicted.

FeNO results were interpreted as being i) low for values < 25ppb; ii) elevated for values 25 - 50ppb; and iii) high for values > 50ppb. A FeNO level > 50 ppb in the absence of a recent upper respiratory tract infectionis generally considered to indicate the presence of eosinophilic airway inflammation associated with allergic asthma (19, 20).

Additional information on the *host-associated risk factors* was obtained from the questionnaire and allergy tests (for atopy). Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared. Smoking status was classified into three categories: non-smoker as lifelong abstinence from smoking; ex-smoker if ceased smoking completely more than 1-month before the survey; and current smoker. A family history of allergy was defined as a positive answer to the question: Do or did any members of your family (blood relatives) ever have any kind of allergies? Individuals with atopy were defined as those subjects having a positive Phadiatop test. Hay-fever was defined as a positive response to the question ”have you ever had any nose or eye problems or allergies such as hay fever?” Childhood-onset asthma was defined as doctor-diagnosed asthma at the age of 16 years or younger, while adult-onset asthma defined as doctor diagnosed asthma at 17 years or older.

Information on the *environmental risk factors* was also based on information obtained from the questionnaire, which had detailed information on the occupational history: employment duration in factory and current job (in years), working area and tasks, woods and chemicals used in production process. The questionnaire also contained information on type of cleaning activities, use of personal protective equipment, health and safety training and episodes of high dust exposure causing symptoms. For the purposes of this analysis, wood processing exposure categories were based on workers belonging to a similarly exposed group (21). Maintenance and upholsterer were regarded as belonging to the lowest exposure category; machine operator, painter-varnisher and assembler to the medium exposure category; and planer, sander, sawyer and carver to the high exposure category.

6.2.7 Statistical analysis

All analyses were conducted using STATA version 12. Continuous indices of FeNO were log transformed (natural log) before linear regression analysis was conducted and the results reported as geometric mean ratios and confidence intervals. Unadjusted logistic and linear and logistic regression analysis was conducted to explore the association between adverse health outcomes (e.g. asthma symptom score, work-related ocular nasal symptoms, work-related asthma symptoms, fixed airway obstruction, bronchial reversibility, FeNO≥ 50 ppb) and host-related attributes (e.g. age, gender, BMI, atopy, childhood-onset asthma, adult-onset asthma, repeated childhood chest infections).

Furthermore, unadjusted linear and logistic regression models were also developed to assess the relationship between relevant adverse health outcomes and self-reported occupational exposures (e.g. employment duration in factory, wood processing exposure categories, type of woods processed, chemicals used, cleaning activities). Multivariate linear and logistic regression models were adjusted for age, gender and smoking since these variables appeared to be the most consistent significant potential confounders identified in the univariate models. The results of these regression models are expressed as odds ratios and confidence intervals.

6.3 RESULTS

6.3.1 Individual host risk factors associated with work-related respiratory symptoms in unadjusted regression models

In unadjusted models, the study demonstrated that higher asthma symptom scores (ASS) were significantly associated in women workers and those with a history of adult-onset asthma and a family history of allergy (Table 6.1a). A past medical history of repeated childhood chest infections, chronic bronchitis and pulmonary tuberculosis were also associated with higher ASS.

Workers with work-related ocular nasal symptoms were also more likely to be female (OR=2.3-2.6) and to be younger workers. Workers with a history of work-related ocular nasal symptoms were much more likely to be atopic (OR= 2.04, 95% CI: 1.20 – 3.47). As for a history of work-related asthma symptoms (WRAS), this was more likely in workers with hay fever (rhinitis) (OR= 1.97, 95%CI: 1.15 – 3.35) and in current smokers (OR= 1.97, 95% CI: 1.02 – 3.80).

6.3.2 Individual host risk factors associated with airway obstruction, bronchial reversibility and exhaled nitric oxide (FeNO) in unadjusted regression models

Using lung function parameters as the outcome variables, airway obstruction was strongly associated with a previous history of tuberculosis (OR= 4.41, 95% CI: 1.93 – 10.06) and in current smokers (OR= 2.67, 95% CI: 1.48 – 4.83) (Table 6.1b). Weak associations were observed between increasing age and airway obstruction (OR= 1.04, 95% CI: 1.02 – 1.06) or airway reversibility (PBD ≥12% and ≥200 ml FEV_1 increase) (OR= 1.06, 95% CI: 1.02 – 1.10). No other host factors were independently associated with bronchial reversibility using either of the two definitions. However, for FeNO a history of either adult-onset asthma or childhood-onset asthma were significantly positively associated with this outcome as was, being male (OR= 1.33, 95% CI: 1.05 – 1.69) or atopic (OR= 1.16, 95% CI: 1.03 – 1.31). As expected, smokers had lower FeNO levels. In workers with FeNO ≥ 50 ppb, very strong associations were found among those who reported childhood-onset asthma (OR= 4.98, 95% CI: 1.53 – 16.22) or who were atopic (OR= 2.85, 95% CI: 1.09 – 7.44).

Table 6.1a: Association between work-related respiratory symptoms and individual host risk factors among wood processing workers in Mozambique based on unadjusted regression models

	Prevalence n (%)	Asthma symptom score (≥2 vs 0-1)	Work-related ocular-nasal symptoms (ever)[a]	Work-related ocular-nasal symptoms[b]	Work-related asthma symptoms (ever)[a]	Work-related asthma symptoms[b]
Prevalence: n (%)		45 (10%)	182 (40)	88 (20)	65 (14)	36 (8)
Demographic characteristics						
Age	38 ± 13	1.00 (0.97 – 1.02)	**0.98 (0.96 – 0.99)****	0.99 (0.97 – 1.00)	1.00 (0.99 – 1.03)	1.00 (0.97 – 1.02)
Gender (%Male vs Female)	94:6	**0.36 (0.14 – 0.93)***	**0.44 (0.20 – 0.98)***	**0.38 (0.17 – 0.81)***	1.37 (0.40 – 4.70)	1.09 (0.25 – 4.81)
BMI	23 ± 4	0.97 (0.88 – 1.06)	**0.94 (0.88 – 0.99)***	0.96 (0.90 – 1.03)	0.99 (0.92 – 1.06)	1.01 (0.93 – 1.10)
Smoking history‡						
Ex-smokers	41 (9)	1.04 (0.35 – 3.11)	0.68 (0.34 – 1.36)	0.75 (0.30 – 1.87)	1.72 (0.74 – 3.97)	1.25 (0.42 – 3.78)
Current smokers	69 (15)	1.44 (0.66 – 3.18)	1.19 (0.71 – 2.01)	1.67 (0.92 – 3.03)	**1.97 (1.02 – 3.80)***	0.91 (0.34 – 2.44)
Allergy history						
Family history of allergy	157 (35)	**2.86 (1.53 – 5.36)****	1.35 (0.91 – 2.01)	1.46 (0.91 – 2.56)	1.39 (0.81 – 2.38)	1.98 (0.99 – 3.92)
Atopy (positive Phadiatop)	194 (50)	1.71 (0.87 – 3.37)	1.24 (0.83 – 1.87)	**2.04 (1.20 – 3.47)****	0.86 (0.49 – 1.52)	1.26 (0.60 – 2.62)
Medical history						
Hay fever	153 (34)	1.64 (0.88 – 3.05)	**2.93 (1.95 – 4.38)*****	NC	**1.97 (1.15 – 3.35)***	1.26 (0.62 – 2.54)
Childhood-onset (≤16 yrs) asthma	23 (5)	1.98 (0.64 – 6.11)	1.65 (0.71 – 3.82)	1.48 (0.57 – 3.88)	1.70 (0.61 – 4.75)	**CS**
Adult-onset (>16 yrs) asthma	5 (1)	**CS**	0.98 (0.16 – 5.93)	1.03 (0.11 – 9.32)	**CS**	**CS**
Repeated childhood chest infections	17 (4)	**4.09 (1.37 – 12.21)***	1.03 (0.38 – 2.76)	0.88 (0.25 – 3.12)	2.59 (0.88 – 7.61)	**3.86 (1.19 – 12.51)***
Chronic bronchitis	4 (1)	**9.37 (1.29 – 68.22)***	4.47 (0.46 – 43.36)	4.19 (0.58 – 30.14)	1.99 (0.20 – 19.42)	3.91 (0.40 – 38.63)
Pulmonary tuberculosis	27 (6)	**2.81 (1.07 – 7.39)***	1.01 (0.46 – 2.24)	0.50 (0.15 – 1.69)	1.76 (0.68 – 4.55)	2.13 (0.69 – 6.52)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001; Asthma symptom score: short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath; ‡current or ex-smokers vs never smokers; [a]Symptoms (chest/ ocular-nasal) ever experienced at work; [b]Symptoms (chest/ ocular-nasal) experienced at work that improves when away from work; NC: not calculable; CS: chi-square test significant p<0.05; Each OR represents a separate unadjusted regression model

Table 6.1b: Association between individual host factors in relation to airway obstruction, airway reversibility and exhaled nitric oxide among wood processing workers in Mozambique based on unadjusted regression models

	Prevalence n (%)	Baseline $FEV_1/FVC < 0.7$	PBD ≥12% and ≥200 ml FEV_1 increase	PBD ΔFEV1% ≥9% of predicted FEV_1	FeNO, ppb‡‡	FeNO≥ 50 ppb
Prevalence: n (%)		83 (19)	14 (3)	24 (6)		22 (5)
Demographic characteristics						
Age	38 ± 13	**1.04 (1.02 – 1.06)*** **	**1.06 (1.02 – 1.10)** **	1.02 (0.99 – 1.05)	1.00 (0.99 – 1.01)	0.97 (0.94 – 1.01)
Gender (%Male vs Female)	94 : 6	1.78 (0.52 – 6.09)	NC	0.70 (0.16 – 3.17)	**1.33 (1.05 – 1.69)***	1.38 (0..18 – 10.68)
BMI	23 ± 4	0.98 (0.92 – 1.05)	1.05 (0.96 – 1.16)	1.08 (1.00 – 1.16)	1.01 (0.99 – 1.03)	1.00 (0.89 – 1.11)
Smoking history‡						
Ex-smokers	41 (9)	1.95 (0.89 – 4.27)	1.61 (0.34 – 7.56)	0.40 (0.05 – 3.04)	1.16 (0.95 – 1.42)	0.40 (0.05 – 3.03)
Current smokers	69 (15)	**2.67 (1.48 – 4.83)** **	0.44 (0.06 – 3.47)	0.45 (0.10 – 1.98)	**0.84 (0.71 – 0.98)***	NC
Allergy history						
Family history of allergy	157 (35)	0.89 (0.53 – 1.47)	0.50 (0.14 – 1.83)	0.94 (0.39 – 2.24)	1.06 (0.94 –1.20)	1.62 (0.68 – 3.84)
Atopy (positive Phadiatop)	194 (50)	0.94 (0.56 – 1.58)	1.17 (0.35 – 3.91)	0.79 (0.32 – 1.94)	**1.16 (1.03– 1.31)***	**2.85 (1.09 – 7.44)***
Medical history						
Hay fever	153 (34)	0.72 (0.43 – 1.21)	0.14 (0.18 – 1.06)	0.35 (0.12 – 1.06)	1.03 (0.91 – 1.16)	1.35 (0.56 – 3.22)
Childhood-onset (≤16 yrs) asthma	23 (5)	1.75 (0.66 – 4.66)	1.58 (0.20 – 12.71)	0.87 (0.11 – 6.78)	**1.31 (1.01 – 1.72)***	**4.98 (1.53 – 16.22)*** **
Adult-onset (>16 yrs) asthma	5 (1)	1.06 (0.12 – 9.62)	NC	5.74 (0.57 – 57.35)	**2.29 (1.34 – 3.94)*** **	4.96 (0.53 – 46.39)
Repeated childhood chest infections	17 (4)	1.43 (0.45 – 4.57)	2.17 (0.27 – 17.77)	1.20 (0.15 – 9.49)	1.01 (0.75 – 1.38)	1.29 (0.16 – 10.23)
Chronic bronchitis	4 (1)	2.13 (0.19 – 23.82)	NC	NC	0.88 (0.44 – 1.77)	NC
Pulmonary tuberculosis	27 (6)	4.41 (1.93 – 10.06)***	1.35 (0.17 – 10.82)	0.75 (0.10 – 5.77)	1.19 (0.93 – 1.51)	0.75 (0.10 – 5.84)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001;
‡current or ex-smokers vs never smokers; Airway obstruction: baseline FEV_1 /FVC < 70%;Airway reversibility:≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD ΔFEV_1% ≥9% of the predicted FEV_1; FeNO: Fractional exhaled nitric oxide; ‡‡Geometric mean ratio (95% CI);
NC: not calculable; Each OR represents a separate unadjusted regression model

6.3.3 Self-reported environmental risk factors associated with work-related respiratory symptoms in unadjusted regression models

With regard to potential environmental risk factors that were reported by workers, there were some important trends. An exposure-response relationship was observed between having a history of having work-related ocular nasal symptoms (WRONS) and belonging to the medium exposure group comprising machine operators, painter-varnishers and assemblers (OR= 3.31, 95% CI: 1.09 – 10.00), and the high exposure group comprising planers, sanders, sawyers and carvers (OR= 4.67, 95% CI: 1.42 – 15.34) (Table 6.2a). Furthermore, those with work-related asthma symptoms were also more likely to report an episode of high dust exposure causing symptoms (OR= 12.19, 95% CI: 1.09 – 136.44).

Working with certain wood species were strongly associated with both upper and lower airway symptoms. Working with Mutondo wood species was associated with having work-related ocular nasal symptoms (OR= 1.92, 95% CI: 1.07 – 3.45) as well aswork-related asthma symptoms (OR= 2.76, 95% CI: 1.29 – 5.91). Other wood species such as Missanda, Panga-panga and Mahogany bean, were strongly associated with a history of having work-related ocular-nasal symptoms.

Surprisingly, employment duration as well as working with chemicals (glues, solvents and varnishes) were negatively correlated with work-related ocular-nasal symptoms in unadjusted models. Similarly, a negative correlation was also observed with cleaning activities.

While, a protective association was observed between work-related ocular-nasal symptoms and wearing a mask (OR= 0.51, 95% CI: 0.27 – 0.96), workers that reported wearing aprons were more likely to have work-related ocular-nasal symptoms (OR= 2.49, 95% CI: 1.10 – 5.66).

Finally, workers with work-related ocular–nasal symptoms were more likely to report having received training on how to protect themselves when working in the wood processing industry (OR= 2.27, 95% CI: 1.34 – 3.84).

Table 6.2a: Self-reported environmental risk factors associated with work-related respiratory symptoms among wood processing workers in Mozambique in unadjusted regression models

	Prevalence n (%)	**Asthma symptom score (≥2 vs 0-1)**	**Work-related ocular nasal symptoms (ever)[a]**	**Work-related ocular nasal symptoms[b]**	**Work-related asthma symptoms (ever)[a]**	**Work-related asthma symptoms[b]**
Prevalence: n (%)		45 (10%)	182 (40)	88 (20)	65 (14)	36 (8)
Environmental factors						
Employment duration in factory		0.99 (0.95 – 1.03)	**0.98 (0.95 – 0.99)***	0.99 (0.96 – 1.02)	1.02 (0.99 – 1.05)	1.01 (0.97 – 1.05)
Employment duration in current job		0.98 (0.94 -1.03)	0.97 (0.95 – 1.00)	0.99 (0.96 – 1.02)	0.99 (0.96 – 1.03)	0.98 (0.93 – 1.03)
Wood processing exposure categories						
Low exposure group: Maintenance and Upholsterer [n=24 (8%)]		1	1	1	1	1
Medium: Machine operator, Painter-varnisher and Assembler [n=226 (73%)]		2.48 (0.32 – 19.26)	**3.31 (1.09 – 10.00)***	1.28 (0.36 – 4.53)	1.15 (0.33 – 4.10)	2.61 (0.34 – 20.20)
*High:*Planer, Sander, Sawyer and Carver [n=58 (19%)]		2.17 (0.24 – 19.62)	**4.67 (1.42 – 15.34)***	2.02 (0.52 – 7.86)	1.83 (0.47 – 7.16)	1.70 (0.18 – 16.08)
Working with chemicals						
Glues	160 (36)	0.71 (0.36 – 1.40)	0.86 (0.58 – 1.28)	**0.43 (0.25 – 0.75)****	1.16 (0.67 – 1.99)	1.33 (0.66 – 2.65)
Dyes	33 (7)	0.89 (0.26 – 3.05)	0.62 (0.29 – 1.33)	0.55 (0.19 – 1.60)	0.36 (0.08 – 1.55)	0.34 (0.05 – 2.57)
Solvents	33 (7)	1.68 (0.62 – 4.60)	0.45 (0.20 – 1.01)	**0.12 (0.02 – 0.88)***	0.57 (0.17 – 1.93)	1.66 (0.55 – 5.01)
Varnishes	103 (23)	0.83 (0.38 – 1.78)	**0.53 (0.33 – 0.85)****	**0.42 (0.21 – 0.82)***	0.82 (0.43 – 1.57)	1.33 (0.62 – 2.85)
Hardeners	37 (8)	0.78 (0.23 – 2.65)	0.69 (0.34 – 1.40)	0.34 (0.10 – 1.14)	0.70 (0.24 – 2.04)	1.02 (0.30 – 3.49)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001;
Asthma symptom score: short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath; [a]Symptoms (chest/ ocular-nasal) ever experienced at work; [b]Symptoms (chest/ ocular-nasal) experienced at work that improves when away from work;
NC: not calculable; CS: chi-square test significant p<0.05; Each OR represents a separate unadjusted regression model

Table 6.2a (continued): Self-reported environmental risk factors associated with work-related respiratory symptoms among wood processing workers in Mozambique in unadjusted regression models

	Prevalence n (%)	Asthma symptom score (≥2 vs 0-1)	Work-related ocular nasal symptoms (ever)[a]	Work-related ocular nasal symptoms[b]	Work-related asthma symptoms (ever)[a]	Work-related asthma symptoms[b]
Prevalence: n (%)		45 (10%)	182 (40)	88 (20)	65 (14)	36 (8)
Environmental factors						
Type of woods						
Panga-panga	248 (55)	0.62 (0.33 – 1.15)	**2.12 (1.43 – 3.12)*** **	0.82 (0.51 – 1.51)	0.66 (0.39 – 1.11)	0.90 (0.46 – 1.79)
Mahogany bean	337 (75)	0.72 (0.37 – 1.40)	**1.82 (1.15 – 2.87)***	0.87 (0.51 – 1.47)	0.72 (0.40 – 1.27)	1.43 (0.61 – 3.35)
African teak	338 (75)	0.80 (0.40 – 1.58)	1.37 (0.88 – 2.14)	0.92 (0.54 – 1.57)	0.84 (0.47 – 1.52)	1.41 (0.60 – 3.31)
Lebombo ironwood	126 (28)	1.48 (0.77 – 2.83)	0.91 (0.60 – 1.39)	0.66 (0.38 – 1.14)	1.17 (0.66 – 2.07)	1.95 (0.97 – 3.92)
African mahogany	98 (22)	1.53 (0.77 – 3.04)	1.40 (0.89 – 2.21)	0.76 (0.42 – 1.38)	1.21 (0.65 – 2.23)	1.65 (0.78 – 3.49)
Pine	189 (42)	0.91 (0.49 1.71)	**0.65 (0.44 – 0.95)***	0.62 (0.38 – 1.01)	1.05 (0.62 – 1.79)	0.99 (0.49 – 1.97)
African sandalwood	35 (8)	0.83 (0.24 – 2.84)	0.98 (0.48 – 1.98)	0.67 (0.25 – 1.77)	0.75 (0.26 – 2.20)	1.54 (0.51 – 4.65)
Mutondo	68 (15)	0.85 (0.35 – 2.10)	**6.93 (3.76 – 12.77)*** **	**1.92 (1.07 – 3.45)***	**2.32 (1.24 – 4.34)** **	**2.76 (1.29 – 5.91)** **
Zebrawood	14 (3)	1.52 (0.33 – 7.03)	1.49 (0.51 – 4.33)	0.68 (0.15 – 3.09)	0.45 (0.06 – 3.48)	3.33 (0.89 – 12.53)
Missanda	129 (29)	0.79 (0.39 – 1.61)	**5.74 (3.67 – 8.98)*** **	**2.56 (1.58 – 4.14)*** **	0.52 (0.27 – 1.01)	1.88 (0.94 – 3.77)
Cleaning activities	380 (84)	1.22 (0.50 – 3.00)	1.27 (0.75 – 2.15)	0.79 (0.43 – 1.46)	1.37 (0.62 – 3.01)	3.34 (0.78 – 14.24)
General cleaning	339 (75)	1.50 (0.44 – 5.12)	0.64 (0.33 – 1.22)	0.81 (0.37 – 1.79)	1.03 (0.41 – 2.58)	1.27 (0.37 – 4.37)
Cleaning equipment	348 (77)	**0.24 (0.10 – 0.57)** **	0.52 (0.25 – 1.07)	1.70 (0.58 – 5.01)	0.74 (0.29 – 1.90)	1.52 (0.35 – 6.65)
Cleaning PPE	345 (77)	0.66 (0.24 – 1.80)	**0.43 (0.21 – 0.88)***	0.65 (0.29 – 1.44)	0.56 (0.24 – 1.30)	1.69 (0.39 – 7.36)
Use of PPE	382 (85)	1.17 (0.48 – 2.89)	1.40 (0.81 – 2.40)	1.16 (0.59 – 2.27)	1.32 (0.60 – 2.90)	1.46 (0.50 – 4.28)
Goggles	187 (49)	1.82 (0.91 – 3.61)	1.08 (0.72 – 1.63)	1.01 (0.61 – 1.68)	1.38 (0.78 – 2.44)	1.10 (0.53 – 2.26)
Gloves	155 (41)	1.41 (0.70 – 2.84)	1.40 (0.92 – 2.13)	1.51 (0.89 – 2.56)	1.20 (0.67 – 2.15)	1.33 (0.62 – 2.85)
Mask	326 (72)	0.94 (0.37 – 2.36)	0.94 (0.53 – 1.67)	**0.51 (0.27 – 0.96)***	1.27 (0.54 – 2.96)	1.73 (0.51 – 5.87)
Aprons	34 (8)	4.05 (0.54 -30.43)	**2.49 (1.10 - 5.66)***	1.18 (0.47 – 2.95	1.90 (0.56 – 6.43)	3.23 (0.43 – 24.41)
Training	272 (60)	1.35 (0.70 – 2.58)	**2.87 (1.90 – 4.33)*** **	**2.27 (1.34 – 3.84)** **	1.44 (0.83 – 2.52)	1.03 (0.51 – 2.07)
Episodes of high dust causing symptoms	3 (1)	4.58 (0.41 – 51.53)	NC	NC	**CS***	NC

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001;
Asthma symptom score: short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath; [a]Symptoms (chest/ ocular-nasal) ever experienced at work; [b]Symptoms (chest/ ocular-nasal) experienced at work that improves when away from work; NC: not calculable; CS: chi-square test significant p<0.05; Each OR represents a separate unadjusted regression model

6.3.4 Environmental risk factors associated with airway obstruction, reversibility and inflammation in unadjusted regression models

There were few environmental predictors of airway changes, most likely due to lack of power. Airway obstruction was positively associated with the exposure to dyes (OR= 2.29, 95% CI: 1.06 – 4.94). On the other hand, bronchial reversibility (PBD ≥12% and ≥200 ml FEV_1) was positively associated withemployment duration in current job (OR= 1.06, 95% CI: 1.01 – 1.12) (Table 6.2b). Furthermore, workers with bronchial reversibility [PBD: ≥9% FEV_1 increase (FEV_1 % predicted)] were more likely to wear gloves (OR= 4.11, 95% CI: 1.18 – 14.30).

As for exhaled nitric oxide, use of masks (OR= 1.24, 95% CI: 1.04 – 1.48), general cleaning activities (OR= 1.23, 95% CI: 1.01 – 1.49), working with glues (OR= 1.15, 95% CI: 1.03 – 1.30), employment duration in the factory (OR= 1.01, 95% CI: 1.00 – 1.01) were associated with increased FeNO, whereas wearing goggles (OR= 0.87, 95% CI: 0.77 – 0.99) and aprons (OR= 0.69, 95% CI: 0.55 – 0.85) were associated with lower FeNO levels in the unadjusted models.

Table 6.2b: Self-reported environmental risk factors associated with airway obstruction and inflammation among wood processing workers in Mozambiquein unadjusted regression models

	Prevalence n (%)	Baseline $FEV_1/FVC <0.7$	PBD ≥12% and ≥200 ml FEV_1 increase	PBD ΔFEV1% ≥9% of predicted FEV_1	FeNO, ppb[‡‡]	FeNO≥ 50 ppb
Prevalence: n (%)		83 (19)	14 (3)	24 (6)	443 (100)	22 (5)
Environmental factors						
Employment duration in factory		1.01 (0.98 – 1.04)	1.04 (0.99 – 1.10)	1.00 (0.95 – 1.05)	**1.01 (1.00 – 1.01)***	1.01 (0.96 – 1.06)
Employment duration in current job		1.00 (0.97 – 1.03)	**1.06 (1.01 – 1.12)***	1.02 (0.97 – 1.07)	0.99 (1.00 – 1.01)	0.98 (0.92 – 1.04)
Wood processing exposure categories						
Low exposure group: Maintenance and Upholsterer [n=24 (8%)]		1	1	1	1	1
Medium: Machine operator, Painter-varnisher and Assembler [n=226 (73%)]		0.85 (0.30 – 2.41)	NC	NC	1.14 (0.88 – 1.48)	1.42 (0.18 – 11.39)
High: Planer, Sander, Sawyer and Carver [n=58 (19%)]		0.81 (0.24 – 2.68)	NC	NC	1.09 (0.81 – 1.46)	1.70 (0.18 – 16.08)
Chemicals						
Glues	160 (36)	1.03 (0.62 – 1.69)	2.48 (0.84 – 7.29)	1.57 (0.68 – 3.59)	**1.15 (1.03 – 1.30)***	2.26 (0.95 – 5.36)
Dyes	33 (7)	**2.29 (1.06 – 4.94)***	2.46 (0.52 – 11.55)	1.30 (0.29 – 5.85)	1.12 (0.90 – 1.27)	2.06 (0.58 – 7.35)
Solvents	33 (7)	1.74 (0.77 – 3.91)	1.05 (0.13 – 8.29)	0.58 (0.08 – 4.42)	1.08 (0.87 – 1.34)	1.26 (0.28 – 5.63)
Varnishes	103 (23)	1.05 (0.60 – 1.83)	0.91 (0.25 – 3.34)	0.66 (0.22 – 1.97)	1.07 (0.93 – 1.23)	1.58 (0.63 – 3.99)
Hardeners	37 (8)	0.69 (0.26 – 1.83)	0.85 (0.11 – 6.68)	0.47 (0.06 – 3.56)	0.96 (0.78 – 1.18)	1.10 (0.25 – 4.91)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001;
Airway obstruction: baseline $FEV_1/FVC < 70\%$;Airway reversibility:≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD $\Delta FEV_1\%$ ≥9% of the predicted FEV_1
FeNO: Fractional exhaled nitric oxide; [‡‡]Geometric mean ratio (95% CI); NC: not calculable; Each OR represents a separate unadjusted regression model

Table 6.2b (continued): Self-reported environmental risk factors associated with airway obstruction and inflammation among wood processing workers in Mozambique in unadjusted regression models

	Prevalence n (%)	Baseline FEV_1/FVC <0.7	PBD ≥12% and ≥200 ml FEV_1 increase	PBD ΔFEV1% ≥9% of predicted FEV_1	FeNO, ppb[‡‡]	FeNO≥ 50 ppb
Prevalence: n (%)		83 (19)	14 (3)	24 (6)	443 (100)	22 (5)
Environmental factors						
Type of woods						
Panga-panga	248 (55)	1.10 (0.68 – 1.79)	0.83 (0.28 – 2.40)	0.48 (0.20 – 1.12)	0.97 (0.88 – 1.08)	0.66 (0.28 – 1.56)
Mahogany bean	337 (75)	0.64 (0.38 – 1.09)	1.99 (0.44 – 9.06)	0.98 (0.38 – 2.53)	1.06 (0.93 – 1.21)	0.69 (0.27 – 1.73)
African teak	338 (75)	0.80 (0.47 – 1.38)	1.22 (0.33 – 4.45)	0.79 (0.32 – 1.96)	1.09 (0.96 – 1.25)	1.10 (0.40 – 3.06)
Lebombo ironwood	126 (28)	0.87 (0.51 – 1.49)	1.02 (0.31 – 3.33)	0.66 (0.24 – 1.80)	1.04 (0.91 – 1.18)	1.20 (0.48 – 3.01)
African mahogany	98 (22)	0.86 (0.48 – 1.55)	0.58 (0.13 – 2.65)	0.15 (0.02 – 1.09)	1.09 (0.95 – 1.26)	0.77 (0.26 – 2.34)
Pine	189 (42)	1.15 (0.71 – 1.86)	1.05 (0.36 – 3.09)	0.69 (0.29 – 1.64)	1.12 (1.00 – 1.26)	1.69 (0.71 – 3.99)
African sandalwood	35 (8)	1.28 (0.56 – 2.94)	NC	NC	1.08 (0.88 – 1.34)	0.54 (0.07 – 4.15)
Mutondo	68 (15)	0.71 (0.35 – 1.46)	2.33 (0.71 – 7.66)	1.52 (0.55 – 4.22)	1.05 (0.89 – 1.23)	0.26 (0.03 – 1.94)
Zebrawood	14 (3)	0.70 (0.15 – 3.19)	NC	NC	1.15 (0.83 – 1.60)	NC
Missanda	129 (29)	0.83 (0.48 – 1.41)	0.39 (0.09 – 1.76)	0.32 (0.09 – 1.11)	0.92 (0.81 – 1.04)	0.37 (0.11– 1.27)
Cleaning activities	380 (84)	NC	0.46 (0.14 – 1.50)	0.94 (0.31 – 2.84)	1.09 (0.93 – 1.27)	1.18 (0.34 – 4.09)
General cleaning	339 (75)	NC	0.25 (0.06 – 1.03)	0.44 (0.14 – 1.38)	**1.23 (1.01 – 1.49)***	1.05 (0.23 – 4.71)
Cleaning equipment	348 (77)	NC	0.79 (0.10 – 6.48)	0.32 (0.10 – 1.03)	1.00 (0.80 – 1.26)	0.73 (0.16 – 3.31)
Cleaning PPE	345 (77)	NC	NC	0.95 (0.21 – 4.27)	1.21 (0.98 – 1.50)	1.84 (0.24 – 14.26)
Use of PPE	382 (85)	NC	0.63 (0.17 – 2.33)	0.87 (0.29 – 2.63)	1.07 (0.91 – 1.26)	1.11 (0.32 – 3.88)
Goggles	187 (49)	NC	1.14 (0.34 – 3.80)	2.31 (0.87 – 6.14)	**0.87 (0.77 – 0.99)***	0.68 (0.27 – 1.73)
Gloves	155 (41)	NC	3.16 (0.67 – 14.85)	**4.11 (1.18 – 14.30)***	0.91 (0.68 – 1.22)	0.74 (0.29 – 1.86)
Mask	326 (72)	NC	1.79 (0.22 – 14.28)	1.64 90.28 – 3.54)	**1.24 (1.04 – 1.48)***	NC
Aprons	34 (8)	NC	0.91 (0.11 – 7.33)	0.81 (0.18 – 3.66)	**0.69 (0.55 – 0.85)****	**0.25 (0.08 – 0.73)***
Training	272 (60)	0.86 (0.53 – 1.40)	0.35 (0.12 – 1.06)	0.44 (0.19 – 1.03)	1.01 (0.90 – 1.14)	0.63 (0.27 – 1.49)
Episodes of high dust causing symptoms	3 (1)	NC	NC	8.63 (0.75 – 98.72)	0.93 (0.46 – 1.86)	NC

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001;
Airway obstruction: baseline FEV_1/FVC < 70%;Airway reversibility:≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD ΔFEV_1% ≥9% of the predicted FEV_1;
FeNO: Fractional exhaled nitric oxide; [‡‡]Geometric mean ratio (95% CI); NC: not calculable; Each OR represents a separate unadjusted regression model.

6.3.5 Self-reported environmental risk factors associated with work-related respiratory symptoms in multivariate regression models

In the multivariate models, adjusted for confounders (age, gender, atopy and smoking), the exposure-response relationship observed between having a history of work-related ocular nasal symptoms (WRONS) and belonging to the medium exposure group (OR= 3.33, 95% CI: 0.93 – 11.91) comprising machine operators, painter-varnishers and assemblers and those belonging to the high exposure group comprising planers, sanders, sawyers and carvers (OR= 4.11, 95% CI: 1.03 – 16.37) persisted (Table 6.3a). Among the wood species that were strongly associated with work-related ocular-nasal symptoms, Mutondo (OR= 2.43, 95% CI: 1.23 – 4.80) and Missanda (OR= 2.29, 95% CI: 1.33 – 3.95) woods were the most consistent. Other wood species such as mahogany bean (OR= 2.52, 95% CI: 1.41 – 4.51), Panga panga (OR= 2.31, 95% CI: 1.49 – 3.60) and African mahogany (OR= 1.65, 95% CI: 1.01 – 2.70) woods were also associated with a history of work-related ocular-nasal symptoms. Furthermore, they were also more likely to use personal protective equipment (OR= 2.09, 95% CI: 1.11 – 3.94) and report having received training on how to protect themselves when working in the wood processing industry (OR= 3.77, 95% CI: 2.34 – 6.06).

With regard to workers with a history of work-related asthma symptoms they were more likely to report an episode of high exposure dust causing symptoms (OR= 13.32, 95% CI: 1.08 – 163.96) and to have received training on how to protect themselves when working in the wood processing industry (OR= 1.94, 95% CI: 1.02 – 3.67). Furthermore, work-related asthma symptoms were strongly associated with exposure to Mutondo wood dust (OR= 3.68, 95% CI: 1.58 – 8.58). On the other hand, cleaning equipment was associated with a relatively lower asthma symptom score (OR= 0.29, 95% CI: 0.10 – 0.83).

Table 6.3a: Self-reported environmental risk factors associated with work-related respiratory symptoms among wood processing workers in Mozambique in multivariate regression models

	Prevalence n (%)	Asthma symptom score (≥2 vs 0-1)	Work-related ocular nasal symptoms (ever)[a]	Work-related ocular nasal symptoms[b]	Work-related asthma symptoms (ever)[a]	Work-related asthma symptoms[b]
Prevalence: n (%)		45 (10%)	182 (40)	88 (20)	65 (14)	36 (8)
Environmental factors						
Employment duration in factory		1.00 (0.95 – 1.05)	1.00 (0.97 – 1.03)	1.03 (0.99 – 1.07)	1.04 (0.99 – 1.08)	1.02 (0.97 – 1.08)
Employment duration in current job		0.99 (0.94 – 1.05)	1.00 (0.97 – 1.04)	1.02 (0.97 – 1.06)	1.00 (0.95 – 1.04)	0.99 (0.93 – 1.05)
Wood processing exposure categories						
Low exposure group: Maintenance and Upholsterer [n=24 (8%)]		1	1	1	1	1
Medium: Machine operator, Painter-varnisher and Assembler [n=226 (73%)]		2.06 (0.26 – 16.40)	3.33 (0.93 – 11.91)	1.49 (0.32 – 6.99)	1.54 (0.33 – 7.11)	1.85 (0.23 – 14.74)
High: Planer, Sander, Sawyer and Carver [n=58 (19%)]		1.72 (0.18 – 16.92)	**4.11 (1.03 – 16.37)***	1.72 (0.32 – 9.43)	3.05 (0.59 – 15.85)	1.02 (0.10 – 10.82)
Working with chemicals						
Glues	160 (36)	0.97 (0.46 – 2.02)	1.12 (0.72 – 1.74)	0.56 (0.31 – 1.03)	1.28 (0.70 – 2.32)	1.39 (0.64 – 3.00)
Dyes	33 (7)	1.20 (0.34 – 4.23)	0.84 (0.37 – 1.88)	0.77 (0.25 – 2.33)	0.44 (0.10 – 1.91)	0.38 (0.05 – 2.94)
Solvents	33 (7)	2.17 (0.76 – 6.17)	0.50 (0.22 – 1.18)	0.14 (0.02 – 1.04)	0.64 (0.18 – 2.20)	1.85 (0.59 – 5.75)
Varnishes	103 (23)	1.07 (0.47 – 2.43)	0.58 (0.35 – 0.96)	0.50 (0.24 – 1.02)	0.84 (0.42 – 1.67)	1.42 (0.63 – 3.23)
Hardeners	37 (8)	1.07 (0.30 – 3.78)	0.76 (0.35 – 1.67)	0.44 (0.13 – 1.53)	0.94 (0.31 – 2.85)	1.16 (0.33 – 4.12)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001;
Asthma symptom score: short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath; [a]Symptoms (chest/ ocular-nasal) ever experienced at work; [b]Symptoms (chest/ ocular-nasal) experienced at work that improves when away from work;;
Each OR represents adjusted for age, gender, atopy and smoking

Table 6.3a (continued): Self-reported environmental risk factors associated with work-related respiratory symptoms among wood processing workers in Mozambiquein multivariate regression models

	Prevalence n (%)	Asthma symptom score (≥2 vs 0-1)	Work-related ocular nasal symptoms (ever)[a]	Work-related ocular nasal symptoms[b]	Work-related asthma symptoms (ever)[a]	Work-related asthma symptoms[b]
Prevalence: n (%)		45 (10%)	182 (40)	88 (20)	65 (14)	36 (8)
Environmental factors						
Type of woods						
Panga-panga	248 (55)	0.73 (0.37 – 1.44)	**2.31 (1.49 – 3.60)*** **	0.74 (0.43 – 1.27)	0.59 (0.33 – 1.06)	1.01 (0.48 – 2.16)
Mahogany bean	337 (75)	1.16 (0.50 – 2.71)	**2.52 (1.41 – 4.51)** **	1.02 (0.53 – 1.97)	0.64 (0.33 – 1.25)	1.97 (0.65 – 5.98)
African teak	338 (75)	1.36 (0.56 – 3.30)	1.53 (0.89 – 2.63)	0.98 (0.51 – 1.89)	0.78 (0.39 – 1.54)	1.93 (0.64 – 5.85)
Lebombo ironwood	126 (28)	1.77 (0.89 – 3.52)	0.91 (0.58 – 1.44)	0.64 (0.35 – 1.18)	1.01 (0.54 – 1.88)	1.99 (0.94 – 4.19)
African mahogany	98 (22)	1.92 (0.92 – 4.01)	**1.65 (1.01 – 2.70)* **	1.00 (0.53 – 1.89)	1.24 (0.64 – 2.40)	1.69 (0.75 – 3.77)
Pine	189 (42)	1.20 (0.59 – 2.44)	0.68 (0.44 – 1.05)	0.81 (0.47 – 1.41)	1.17 (0.65 – 2.10)	0.92 (0.43 – 1.96)
African sandalwood	35 (8)	1.13 (0.32 – 3.98)	0.88 (0.39 – 1.96)	0.76 (0.25 – 2.31)	0.92 (0.30 – 2.80)	1.42 (0.40 – 5.04)
Mutondo	68 (15)	1.10 (0.42 – 2.86)	**9.34 (4.54 – 19.20)*** **	**2.43 (1.23 – 4.80)* **	1.90 (0.92 – 3.94)	**3.68 (1.58 – 8.58)** **
Zebrawood	14 (3)	1.71 (0.36 – 8.26)	1.41 (0.46 – 4.39)	0.75 (0.16 – 3.63)	0.42 (0.05 – 3.38)	2.25 (0.47 – 10.84)
Missanda	129 (29)	0.74 (0.34 – 1.60)	**6.84 (4.17 – 11.20)*** **	**2.29 (1.33 – 3.95)** **	0.55 (0.27 – 1.11)	2.09 (0.99 – 4.41)
Cleaning activities	380 (84)	0.97 (0.38 – 2.45)	1.65 (0.89 – 3.03)	1.16 (0.55 – 2.48)	1.88 (0.71 – 4.96)	2.72 (0.63 – 11.77)
General cleaning	339 (75)	1.02 (0.29 – 3.60)	0.84 (0.39 – 1.79)	0.70 (0.28 – 1.76)	1.19 (0.40 – 3.60)	1.49 (0.33 – 6.62)
Cleaning equipment	348 (77)	**0.29 (0.10 – 0.83)* **	0.55 (0.23 – 1.33)	1.19 (0.38 – 3.77)	0.47 (0.17 – 1.28)	2.29 (0.29 – 17.91)
Cleaning PPE	345 (77)	0.96 (0.30 – 3.11)	0.58 (0.27 – 1.24)	0.80 (0.32 – 1.97)	0.50 (0.20 – 1.22)	3.36 (0.43 – 26.13)
Use of PPE	382 (85)	1.36 (0.50 – 3.70)	**2.09 (1.11 – 3.94)* **	1.68 (0.74 – 3.82)	1.27 (0.54 – 2.98)	2.80 (0.65 – 12.13)
Goggles	187 (49)	1.47 (0.69 – 3.13)	0.87 (0.55 – 1.38)	0.74 (0.41 – 1.33)	1.35 (0.71 – 2.56)	1.34 (0.60 – 2.97)
Gloves	155 (41)	1.17 (0.55 – 2.48)	1.19 (0.75 – 1.89)	1.38 (0.76 – 2.49)	1.24 (0.65 – 2.37)	1.68 (0.73 – 3.89)
Mask	326 (72)	1.84 (0.52 – 6.48)	1.18 (0.59 – 2.35)	0.60 (0.28 – 1.30)	1.11 (0.43 – 2.86)	2.10 (0.47 – 9.40)
Aprons	34 (8)	3.94 (0.51 – 30.37)	2.27 (0.98 – 5.28)	0.93 (0.36 – 2.44)	1.75 (0.50 – 6.11)	3.59 (0.47 – 27.74)
Training	272 (60)	1.39 (0.68 – 2.84)	**3.77 (2.34 – 6.06)*** **	**2.10 (1.17 – 3.78)* **	**1.94 (1.02 – 3.67)* **	0.96 (0.45 – 2.06)
Episodes of high dust causing symptoms	3 (1)	3.77 (0.32 – 44.83)	NC	NC	CS	NC

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001;
Asthma symptom score: short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath; [a]Symptoms (chest/ ocular-nasal) ever experienced at work; [b]Symptoms (chest/ ocular-nasal) experienced at work that improves when away from work;;
NC: not calculable; CS: chi-square test significant p<0.05; Each OR represents adjusted for age, gender, atopy and smoking

6.3.6 Self-reported environmental risk factors associated with airway obstruction, reversibility and inflammation in multivariate regression models

In the multivariate models using lung function indices as the outcome measure, relatively few associations were observed. Airway obstruction was positively associated with exposure to dyes (OR= 3.03, 95% CI: 1.31 – 7.00), but negatively associated with employment duration (OR= 0.96, 95% CI: 0.93 – 0.99) (Table 6.3b). Bronchial reversibility (PBD ≥12% and ≥200 ml FEV_1) was positively associated withwearing gloves (OR= 3.86, 95% CI: 1.05 – 14.18), whereas wearing aprons was negatively associated with FeNO levels (OR= 0.78, 95% CI: 0.63 – 0.97). A similar negative association was also observed between cleaning activities and bronchial reversibility (OR=0.20, 95% CI: 0.05 – 0.79).

Table 6.3b: Self-reported environmental risk factors associated with airway obstruction and inflammation among wood processing workers in Mozambique in multivariable regression models

	Prevalence n (%)	Baseline FEV_1/FVC <0.7	PBD ≥12% and ≥200 ml FEV_1 increase	PBD ΔFEV1% ≥9% of predicted FEV_1	FeNO, ppb‡‡	FeNO≥ 50 ppb
Prevalence: n (%)		83 (19)	14 (3)	24 (6)	443 (100)	22 (5)
Environmental factors						
Employment duration in factory		**0.96 (0.93 – 0.99)***	1.01 (0.95 – 1.08)	0.98 (0.92 – 1.04)	1.01 (1.00 – 1.02)	1.04 (0.97 – 1.12)
Employment duration in current job		**0.96 (0.92 – 0.99)***	1.04 (0.97 – 1.12)	1.01 (0.95 – 1.07)	1.00 (0.99 – 1.03)	0.99 (0.91 – 1.07)
Wood processing exposure categories						
Low exposure group: Maintenance and Upholsterer [n=24 (8%)]		1	1	1	1	1
Medium: Machine operator, Painter-varnisher and Assembler [n=226 (73%)]		0.95 (0.29 – 3.16)	NC	NC	1.14 (0.85 – 1.53)	1.03 (0.12 – 8.81)
High: Planer, Sander, Sawyer and Carver [n=58 (19%)]		1.54 (0.39 – 6.04)	NC	NC	1.15 (0.82 – 1.61)	1.30 (0.13 – 13.32)
Chemicals						
Glues	160 (36)	1.07 (0.61 – 1.88)	2.41 (0.66 – 8.75)	1.67 (0.64 – 4.39)	1.12 (0.99 – 1.28)	2.46 (0.98 – 6.21)
Dyes	33 (7)	**3.03 (1.31 – 7.00)****	2.15 (0.38 – 12.30)	1.20 (0.24 – 5.88)	1.13 (0.89 – 1.42)	1.81 (0.48 – 6.80)
Solvents	33 (7)	2.27 (0.96 – 5.40)	1.22 (0.13 – 11.02)	0.58 (0.07 – 4.61)	1.08 (0.86 – 1.36)	1.11 (0.24 – 5.17)
Varnishes	103 (23)	1.17 (0.63 – 2.17)	0.68 (0.14 – 3.44)	0.50 (0.14 – 1.79)	1.04 (0.90 – 1.20)	1.36 (0.52 – 3.58)
Hardeners	37 (8)	1.14 (0.41 – 3.20)	1.02 (0.11 – 9.35)	0.53 (0.07 – 4.22)	0.96 (0.76 – 1.20)	0.90 (0.20 – 4.18)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001;
Airway obstruction: baseline FEV_1/FVC < 70%;Airway reversibility:≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD ΔFEV_1% ≥9% of the predicted FEV_1; FeNO: Fractional exhaled nitric oxide; ‡‡Geometric mean ratio (95% CI); NC: not calculable; Each OR represents a separate adjusted for age, gender, atopy and smoking

Table 6.3b (continued): Self-reported environmental risk factors associated with airway obstruction and inflammation among wood processing workers in Mozambique in multivariate regression models

	Prevalence n (%)	Baseline $FEV_1/FVC < 0.7$	PBD ≥12% and ≥200 ml FEV_1 increase	PBD ΔFEV1% ≥9% of predicted FEV_1	FeNO, ppb‡‡	FeNO≥ 50 ppb
Prevalence: n (%)		83 (19)	14 (3)	24 (6)	443 (100)	22 (5)
Environmental factors						
Type of woods						
Panga-panga	248 (55)	1.54 (0.88 – 2.69)	0.39 (0.11 – 1.41)	**0.24 (0.85 – 0.70)****	0.91 (0.80 – 1.03)	0.49 (0.20 – 1.18)
Mahogany bean	337 (75)	0.85 (0.45 – 1.63)	1.04 (0.21 – 5.18)	0.66 (0.23 – 1.90)	0.99 (0.85 – 1.15)	0.47 (0.18 – 1.24)
African teak	338 (75)	1.15 (0.58 – 2.28)	0.52 (0.13 – 2.13)	0.52 (0.19 – 1.44)	1.02 (0.87 – 1.19)	0.75 (0.26 – 2.19)
Lebombo ironwood	126 (28)	0.90 (0.50 – 1.61)	1.31 (0.36 – 4.74)	0.76 (0.27 – 2.16)	1.02 (0.86 – 1.12)	1.02 (0.40 – 2.61)
African mahogany	98 (22)	0.75 (0.39 – 1.43)	0.56 (0.12 – 2.75)	0.15 (0.02 – 1.16)	1.01 (0.87 – 1.17)	0.72 (0.23 – 2.24)
Pine	189 (42)	1.30 (0.75 – 2.24)	0.87 (0.25 – 2.99)	0.53 (0.19 – 1.44)	1.04 (0.92 – 1.18)	1.31 (0.53 – 3.21)
African sandalwood	35 (8)	1.22 (0.49 – 3.06)	NC	NC	1.07 (0.85 – 1.35)	0.58 (0.07 – 4.63)
Mutondo	68 (15)	0.54 (0.23 – 1.27)	1.36 (0.26 – 7.08)	1.20 (0.33 – 4.42)	1.11 (0.93 – 1.33)	0.35 (0.05 – 2.74)
Zebrawood	14 (3)	0.67 (0.14 – 3.20)	NC	NC	1.10 (0.78 – 1.55)	NC
Missanda	129 (29)	1.14 (0.64 – 2.03)	0.62 (0.13 – 2.98)	0.42 (0.12 – 1.48)	0.91 (0.79 – 1.04)	0.35 (0.10 – 1.24)
Cleaning activities	380 (84)	0.75 (0.36 – 1.53)	**0.20 (0.05 – 0.79)***	0.69 (0.22 – 2.17)	1.06 (0.89 – 1.26)	1.16 (0.32 – 4.14)
General cleaning	339 (75)	0.84 (0.32 – 2.23)	0.15 (0.02 – 1.04)	0.45 (0.12 – 1.72)	1.22 (0.97 – 1.52)	0.96 (0.21 – 4.47)
Cleaning equipment	348 (77)	0.64 (0.22 – 1.91)	NC	0.29 (0.07 – 1.20)	0.92 (0.71 – 1.20)	0.57 (0.12 – 2.76)
Cleaning PPE	345 (77)	0.70 (0.27 – 1.80)	NC	0.91 (0.18 – 4.62)	1.21 (0.96 – 1.52)	1.83 (0.22 – 14.88)
Use of PPE	382 (85)	0.96 (0.45 – 2.06)	0.49 (0.12 – 2.04)	0.75 (0.24 – 2.38)	1.12 (0.94 – 1.33)	1.31 (0.37 – 4.68)
Goggles	187 (49)	0.96 (0.52 – 1.77)	1.44 (0.33 – 6.22)	2.96 (0.96 – 9.09)	0.97 (0.84 – 1.11)	1.03 (0.39 – 2.70)
Gloves	155 (41)	0.94 (0.52 – 1.71)	3.10 (0.59 – 16.20)	**3.86 (1.05 – 14.18)***	0.90 (0.79 – 1.03)	0.91 (0.35 – 2.37)
Mask	326 (72)	1.02 (0.43 – 2.41)	1.00 (0.12 – 8.59)	0.58 (0.16 – 2.20)	1.21 (0.99 – 1.48)	NC
Aprons	34 (8)	1.39 (0.48 – 3.98)	1.04 (0.11 – 9.41)	0.67 (0.14 – 3.22)	**0.78 (0.63 – 0.97)***	0.37 (0.12 – 1.15)
Training	272 (60)	0.91 (0.52 -1.59)	0.46 (0.12 – 1.71)	0.73 (0.29 – 1.83)	0.99 (0.88 – 1.13)	0.63 (0.26 – 1.54)
Episodes of high dust causing symptoms	3 (1)	NC	NC	8.35 (0.65 – 106.49)	1.06 (0.52 – 2.14)	NC

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001; Airway obstruction: baseline $FEV_1/FVC < 70\%$;%;Airway reversibility:≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD $\Delta FEV_1\%$ ≥9% of the predicted FEV_1; FeNO: Fractional exhaled nitric oxide; ‡‡Geometric mean ratio (95% CI); NC: not calculable; Each OR represents a separate adjusted for age, gender, atopy and smoking

6.4 DISCUSSION

This study has reported some important environmental and host-associated factors in wood workers with work-related ocular-nasal and asthma symptoms. One of the novel components of this current study is the identification of particular indigenous exotic wood species such as Mutondo (*Cordyla Africana*), Missanda (*Erythrophleum suaveolens Brenan*), Panga-panga (*Millettia Stuhlmannii Taub*) and Mahogany bean (*Afzelia quanzensis Welw*.) was strongly associated with work-related ocular nasal symptoms, while with the Mutondo (*Cordyla Africana*) wood species was associated with both work-related ocular-nasal and asthma symptoms. In the exposure assessment component of the overall study (chapter 4), Mahogany bean was one of two wood species that was a significant predictor of elevated dust levels. With regard to the other woods, these symptoms may be related to the size of wood particulate, its physical or chemical properties. It is well-known that dust produced from wood species that is very fine, is likely to be airborne for a longer period of time, and likely to be inhaled.

In this study, various individual host factors were investigated in relationship with either upper or lower airway symptoms. As expected, higher general asthma symptom scores were found in workers reporting a family history of allergy, adult-onset asthma diagnosis, and being female. The increased risk of asthma among women is well described and various reasons have been put forward that relate to biological factors (sex hormones), the gendered distribution of work, and domestic-related chores (22). While only 6% of study subjects in the current study were women workers, almost half (44%) were engaged in general cleaning, cooking with biomass fuel and wood treatment, in which the level of exposure to dust, chemicals, fumes, vapors and gases was high. Increasing age was also associated with the presence of clinically significant bronchial reversibility as is frequently observed in asthma. This is consistent with previously reported studies on risk factors associated with adult asthma (23). The presence of airway obstruction was also more likely in workers with increasing age, current smoking and those reporting a previous history of tuberculosis. This is consistent with other studies that have been previously reported in South Africa and beyond (24, 25, 26, 27).

With regard to work-related asthma symptoms (WRAS) in wood workers, the findings of this study demonstrated that this was more likely to be observed in current smokers and those with hay fever (rhinitis). While the evidence for the role of smoking in occupational asthma remains inconsistent, some studies have shown some associations in wood workers. Ugheoke et al

(28)in their study of Nigerian sawmill workers reported that smoking aggravated respiratory symptoms, while Schlunssen et al.(2) demonstrated that the prevalence ofwork-related asthma symptoms in Danish wood workers was higher in smokers compared to non-smokers. Furthermore,Tobin et al. (7) among Nigerian sawmill workers found that there was a significantly higher prevalence of asthma-related symptoms among current and ex-smokers compared to non-smokers. More recently, Neghab et al. (9) also demonstrated that the prevalence of respiratory symptoms was significantly higher among smokers than non-smokers. Furthermore, the prevalence among workers exposed to cigarette smokers was also higher. However,Chaiear et al. (8) reported a negative association between current smoking or exposure to second hand tobacco smoke and upper respiratory symptoms among Thai rubber wood sawmill workers. With regard to rhinitis, various studies have shown that upper airway symptoms and rhinitis commonly precedes occupational asthma and is considered a risk factor for the development of occupational asthma (4,5).

The determinants of exhaled nitric oxide (FeNO) in wood workers have not been explored previously. in this current study workers that were male, atopic, or who had asthma were the major determinants of increasing levels of FeNO in wood workers, as has been frequently observed in other occupational studies and should be considered as potential confounders (29). The higher FeNO levels observed in men is also in keeping with those recently reported from the European Community Respiratory Health Survey III (30), which found that FeNO levels were 21% higher in men compared with women. The findings for atopy are also well documented in other Southern African studies of spice mill and bakery workers (31,32). Similarly, the negative association between smoking and FeNO observed in this study is also consistent with other occupational settings (30,31,32). In order to take into consideration, the effect of atopy or smoking on FeNO the results were adjusted accordingly to provide more robust estimates for the associations observed.

Among the self-reported environmental predictors for work-related symptoms, an exposure-response relationship was observed between having a history of work-related ocular nasal symptoms (WRONS) and belonging to the medium exposure group comprising machine operators, painter-varnishers and assemblers (OR= 3.31, 95% CI: 1.09 – 10.00), and the high exposure group comprising planers, sanders, sawyers and carvers (OR= 4.67, 95% CI: 1.42 – 15.34). These exposure groups correlated with dust exposure levels in these exposure categories, in that the high exposure category had mean dust levels of 6.99 - 10.84 mg/m^3 and the medium exposure category, levels of 1.80 - 4.71 mg/m^3, whereas the maintenance group that was used as the baseline comparator group had mean levels of 1.80 mg/m^3. The associations observed in this study were similar to those reported for Tanzanian small-scale wood Industries (14), Danish and British woodworkers (33, 34).

When considering more objective indices of asthma in relation to occupational risk factors, employment duration in the factory as well as in the current job was significantly associated with both reversible airway obstruction and increasing levels of FeNO, suggesting further evidence of an exposure response relationship in wood workers. With regard to reversible airway obstruction, the findings of this study are also consistent with other studies among wood processing workers in Africa and beyond (10, 11, 12) that have reported similar associations. To our knowledge, there have not been other published studies in wood workers assessing the relationship between employment duration and FeNO among wood processing workers (29).

Wood working is also associated with concomitant exposure to chemicals used in the production process. In the present study, working with dyes was associated with airway obstruction as has been reported previously by Talini et al. (3), in which the prevalence of bronchitis was high in spray painters compared to wood workers involved in furniture manufacture. Working with glues was also associated with elevated FeNO, a finding reported in Greek furniture workers (16), in which levels were elevated in chemical exposed workers compared to the wood and office workers. An Iranian study also reported a high prevalence of work-related respiratory and allergic symptoms among carpenters exposed to chemicals when compared to a control group (35). It is well known that exposure to dyes and solvents is associated with a high risk of airway obstruction (36). Considering the main types of glue used in the Mozambique wood processing industry, the safety data sheets indicate that the products are mainly irritant in nature aside from a resin called Polyvinyl Formal (polyvinyl alcohol with formaldehyde). It is well known that exposure to formaldehyde is associated with respiratory symptoms such as irritation, allergies and asthma (37, 38).

The associations between cleaning activities and the risk of adverse upper and lower respiratory health outcomes were consistent. Cleaning equipment was significantly associated with a relatively lower asthma symptom score (OR= 0.29, 95% CI: 0.10 – 0.83) as was general cleaning activities and bronchial reversibility (OR=0.20, 95% CI: 0.05 – 0.79) in the final adjusted multivariate models. The protective respiratory health effect of cleaning activities is consistent with the findings of the exposure assessment part of study (chapter 4), in which tasks involving cleaning of equipment, especially using damp rags, was associated with decreased dust levels in the final multivariate models obtained for wood dust particulate levels. This finding reinforces the principle of following optimal occupation hygiene practices in these settings. A series of measures have also been proposed by various studies in order to reduce exposure to wood dust, which include maintenance of tools, good work practices, and other occupational hygiene measures (39, 40, 41, 42).

In current study, the effect of personal protective equipment (PPE) appeared contradictory. In the multivariate models, general use of PPE was associated with an increased risk of WRONS (OR = 2.09) as was use of gloves with increased risk of bronchial reversibility (OR = 3.86). Surprisingly, only the use of aprons appeared protective, being significantly associated with lower FeNO levels (OR = 0.78). These findings appear counterintuitive since use of aprons is likely to increase WRONS since wood dust can easily settle on them and become airborne when shaken. This is probably also the reason for the association with bronchial reversibilityin that while gloves may provide hand skin protection, they have no protective role in terms of inhalation. Given that these associations cannot easily be assessed in a cross-sectional study, it is likely that the positive association between use of PPE and the increased risk of WRONS is likely to be a proxy for high dust exposure needing protection. Studies in the furniture industry and in other settings have shown a lower prevalence of respiratory symptoms in workers who wore respiratory protection (43, 44). However, while respiratory protective equipment may reduce symptoms they are not totally protective since their effectiveness is dependent on using appropriate respiratory protective equipment selected for their capacity to filter particulate exposures of a particular size and adequate fit-testing to ensure optimal protection(45). Generally, the PPE used in the factories in this current study, were inappropriate, in that most workers wore polypropylene masks (without any filters), that were not changed regularly and not stored in clean lockers, resulting in ongoing dust contamination. Further research using a longitudinal study design could shed better light on the impact of workplace control measures, including respiratory protective equipment, on the respiratory health of wood workers.

In the final multivariate models, workers with WRONS and WRAS were more likely to have received training on dust control measures and how to protect themselves. Due to the cross-sectional nature of the current study, temporality could not be established, and as a result the effect of training could not be established. However, it is probable that training was provided subsequent to the high prevalence of WONS and WRAS reported by the workers. To our knowledge, there are no studies that have investigated the effectiveness of occupational health and safety training programmes in reducing the incidence of work-related asthma in wood processing workers. However, studies in other settings have shown that workplace education and training programs can have a positive impact on health and safety behaviors and wood dust levels(39). However, OHS training as a sole intervention, without any other control measures in the workplace, has not been demonstrated to have a protective impact on respiratory health (46, 47). Furthermore, other factors related to the designed and implementation aspects can also impact on the effectiveness of such programmes (48). There is a need for further research on the impact of different interventions on the risk of rhinitis and asthma in wood processing workers.

This current study has some novel and important strengths worthy of highlighting. A comprehensive assessment of risk factors associated with multiple indices of work-related asthma that included work-related respiratory symptoms, bronchial reversibility (using two different definitions) and airway inflammation (FeNO). To our knowledge, this is the first study to report that inhalational exposure to certain wood species, Missanda (*Erythrophleum suaveolens Brenan*), Panga-panga (*Millettia Stuhlmannii* Taub) and Mahogany bean (*Afzelia quanzensis Welw.*),is associated with work-related ocular nasal symptoms and Mutondo wood (Cordyla Africana) with both work-related ocular-nasal symptoms and asthma symptoms. Furthermore, a dose-response relationship was observed between having a history of work-related upper and lower airway symptoms, and belonging to medium and high dust exposure categories, as reported by the workers.

Despite the important insights gained into individual host and environmental risk factors associated with adverse respiratory health outcomes using objective markers for rhinitis and asthma, there were certain limitations. The cross-sectional nature of the study design did not allow for establishing temporality between exposure and the outcomes of the counterintuitive associations observed use of PPE or training and the risk of WRONS and WRAS. Additionally, we could not explain why Missanda and Panga-panga were associated with WRONS and Mutondo was associated with both work-related upper and lower respiratory symptoms. The possibility of reporting bias could not be totally excluded in this study. While this study used multiple comparisons in order to ascertain the relationships of interest, it is possible that spurious observations could have arisen. However, the consistent associations observed are indeed biological plausible and further support the relationships observed.

6.5 CONCLUSION

This study has demonstrated that the main host factors associated with t work-related upper ocular-nasal and asthma symptoms include age, gender and atopy. Exposure to wood dust of particular species such as Missanda (*Erythrophleum suaveolens Brenan*), Panga-panga (*Millettia Stuhlmannii Taub*) and Mahogany bean (*Afzelia quanzensis Welw.*) woods was associated with mainly work-related upper airway symptoms, while exposure to Mutondo (Cordyla Africana) wood dust was associated with both work-related ocular-nasal symptoms and asthma symptoms.

6.5 REFERENCES

1. Pérez-Ríos M, Ruano-Ravina A, Etminan M, Takkouche B. A meta-analysis on wood dust exposure and risk of asthma. Allergy. 2010;65(4):467–73.
2. Schlunssen V, Schaumburg I, Heederik D, Taudorf E et al. Indices of asthma among atopic and non-atopic woodworkers. Occup Environ Med. 2004;61(6):504–11.
3. Talini D, Monteverdi A, Benvenuti A, Petrozzino M, Di Pede F, Lemmi M, et al. Asthma-like symptoms, atopy, and bronchial responsiveness in furniture workers. Occup Environ Med.1998;55(11):786–91.
4. Jeebhay, M. F. and Adewole OO. Work-Related Asthma (WRA). AOEC. 2012;(1):93–108.
5. Moscato G, Vandenplas O, Van Wijk RG, Malo J-L, Perfetti L, Quirce S, et al. EAACI position paper on occupational rhinitis. Respir Res. 2009;10:16.
6. Aguwa EN, Okeke TA, Asuzu MC. The prevalence of occupational asthma and rhinitis among woodworkers in south-eastern Nigeria. Tanzan Health Res Bull. 2007;9(1):52–5.
7. Tobin EA, Ediagbonya TF, Okojie OH, Asogun DA. Occupational Exposure to Wood Dust and Respiratory Health Status of Sawmill Workers in South-South Nigeria. Pollut Eff Control. 2016;4(1):4–9.
8. Chaiear N, Ngoencharee J, Saejiw N. Respiratory Symptoms and Pulmonary Function among Workers in a Rubber Wood Sawmill Factory in Thailand. Am J Public Heal Res. 2018;6(2):65–71.

9. Neghab M, Jabari Z, Kargar Shouroki F. Functional disorders of the lung and symptoms of respiratory disease associated with occupational inhalation exposure to wood dust in Iran. Epidemiol Health. 2018;40:1-8.
10. Bolund ACS, Miller MR, Jacobsen GH, Sigsgaard T, Schlünssen V. New-onset COPD and decline in lung function among wood dust-exposed workers : Re-analysis of a 6-year Follow-up Study. Ann Work Expo Heal. 2018;20(20):1–13.
11. Meo SA. Effects of duration of exposure to wood dust on peak expiratory flow rate among workers in small scale wood industries. Int J Occup Med Environ Health. 2004;17(4):451–5.
12. Shamssain MH. Pulmonary function and symptoms in workers exposed to wood dust. Thorax. 1992;47(2):84–7.
13. Mumuni M. Respiratory health problems among sawmill workers at the timber market, Accra. University of Ghana; 2015.
14. Rongo LMB, Besselink A, Msamanga GI, Dolmans WM V, Demers PA, Heederik D. Respiratory Symptoms and Dust Exposure Among Male Workers in Small-Scale Wood Industries in Tanzania. J Occup Environ Med. 2002;44(12):1153–60.
15. Lytras T, Kogevinas M, Kromhout H, et al.Occupational exposures and 20-year incidence of COPD: the European Community Respiratory Health Survey. Thorax. 2018;0:1–8.
16. Paraskevaidou K, Porpodis K, Kontakiotis T, Kioumis I, Spyratos D, Papakosta D. Asthma and rhinitis in Greek furniture workers. J Asthma. 2019;1–10.
17. Miller MR, Crapo R, Hankinson J, Brusasco V, Burgos F, Casaburi R, et al. General considerations for lung function testing. Eur Respir J. 2005;26(1):153–61.
18. ATS and ERS. ATS/ERS recommendations for standardized procedures for the online and offline measurement of exhaled lower respiratory nitric oxide and nasal nitric oxide, 2005. Am J Respir Crit Care Med. 2005;171(8):912–30.
19. Bjermer L, Alving K, Diamant Z, Magnussen H, Pavord I, Piacentini G, et al. Current evidence and future research needs for FeNO measurement in respiratory diseases. Respir Med. 2014;108(6):830–41.
20. Dweik RA, Boggs PB, Erzurum SC, Irvin CG, Leigh MW, Lundberg JO, et al. An Official ATS Clinical Practice Guideline: Interpretation of exhaled nitric oxide levels (FeNO) for clinical applications. Am J Respir Crit Care Med. 2011;184:602–15.
21. Smit J, Weesp S. The assessment of Exposure Vinyl chloride and 1 , 2-Dichloroethane. ECVM. 2009;44.
22. Moscato G, Apfelbacher C, Brockow K, Eberle C, Genuneit J, Mortz C, et al. GEnder and

occupational allergy (GOA): Report from the task force of the EAACI Environmental & Occupational Allergy Interest Group. Allergy. 2020;28.

23. Jeebhay MF, Ngajilo D, Le Moual N. Risk factors for nonwork-related adult-onset asthma and occupational asthma: A comparative review. Current Opinion in Allergy and Clinical Immunology. 2014;14(2):84–94.
24. Ehrlich R, Adams S, Baatjies R, Jeebhay MF. Chronic airflow obstruction and respiratory symptoms following tuberculosis: A review of South African studies. Int J Tuberc Lung Dis. 2011;15(7):886–91.
25. Menezes AMB, Hallal PC, Perez-Padilla R, Jardim JRB, Muiño A, Lopez M V., et al. Tuberculosis and airflow obstruction: Evidence from the PLATINO study in Latin America. Eur Respir J. 2007;30(6):1180–5.
26. Mattila T, Heliövaara M, Rissanen H, Knekt P, Puukka P, Vasankari T. Tuberculosis, Airway Obstruction and Mortality in a Finnish Population. COPD J Chronic Obstr Pulm Dis. 2017;14(2):143–9.
27. Vasankari T, Härkänen T, Kainu A, Sääksjärvi K, Mattila T, Jousilahti P, et al. Predictors of New Airway Obstruction–An 11 Year's Population-Based Follow-Up Study. COPD J Chronic Obstr Pulm Dis. 2019;16(1):45–50.
28. Ugheoke AJ, Ebomoyi MI, Iyawe VI. Influence of smoking on respiratory symptoms and lung function indices in sawmill workers in Benin City, Nigeria. Niger J Physiol Sci 2006;21(1–2):49–54.
29. Coman I, Lemie C. Fractional exhaled nitric oxide (FeNO) in the screening and diagnosis work-up of occupational asthma. Curr Treat Options Allergy. 2017;4:145–59.
30. Nerpin E, Olivieri M, Gislason T, Olin AC, Nielsen R, Johannessen A, et al. Determinants of fractional exhaled nitric oxide in healthy men and women from the European Community Respiratory Health Survey III. Clin Exp Allergy. 2019;49(7):969–79.
31. Walt A Van Der, Baatjies R, Singh T, Jeebhay MF. Environmental factors associated with baseline and serial changes in fractional exhaled nitric oxide (FeNO) in spice mill workers. Occup Environ Med. 2016;73:614–20.
32. Baatjies R, Jeebhay MF. Sensitisation to cereal flour allergens is a major determinant of elevated exhaled nitric oxide in bakers. Occup Environ Med. 2013;70(5):310–6.
33. Schlünssen V, Schaumburg I, Taudorf E, Mikkelsen AB, Sigsgaard T. Respiratory symptoms and lung function among Danish woodworkers. J Occup Environ Med. 2002;44(1):82–98.
34. Wiggans RE, Sumner J, Robinson E, Barber CM. Respiratory symptoms, lung function

and sensitisation across different exposure groups of British woodworkers. Thorax. 2017;72(3):A1-278.

35. Boskabady MH, Rezaiyan MK, Navabi I, Shafiei S, Arab SS. Work-related respiratory symptoms and pulmonary function tests in northeast iranian (the city of Mashhad) carpenters. Clinics. 2010;65(10):1003–7.
36. Ould-Kadi F, Nawrot TS, Hoet PH, Nemery B. Respiratory function and bronchial responsiveness among industrial workers exposed to different classes of occupational agents: A study from Algeria. J Occup Med Toxicol. 2007;2(1):1–8.
37. Thetkathuek A, Yingratanasuk T, Ekburanawat W. Respiratory Symptoms due to Occupational Exposure to Formaldehyde and MDF Dust in a MDF Furniture Factory in Eastern Thailand. Adv Prev Med. 2016;2016:1–11.
38. Neeraj Mathur SKR. Respiratory effects due to occupational exposure to formaldehyde: Systematic review with meta-analysis. Indian J Occup Environ Med. 2007;11(1):26.
39. Lazovich D, Parker DL, Brosseau LM, Milton FT, Dugan SK, Pan W, et al. Effectiveness of a worksite intervention to reduce an occupational exposure: the Minnesota wood dust study. Am J Public Health. 2002;92(9):1498–505.
40. Schlunssen V, Jacobsen G, Erlandsen M, Mikkelsen AB, et al. Determinants of wood dust exposure in the Danish furniture industry — Results from Two cross-sectional studies 6 years apart determinants of wood dust exposure in the Danish furniture industry — results from two cross-sectional studies 6 years apart. Ann Occup Hyg. 2008;52(4):227–38.
41. Douwes J. Wood dust in joineries and furniture manufacturing: an exposure determinant and intervention study. Ann Work Expo Heal. 2017;61(4):416–28.
42. California Department of Public Health. Wood dust and work-related asthma. 2017.
43. Merry Sunaryo. The Effect of environmental factor and use of personal protective equipment on the symptoms of acute respiratory tract infections in furniture industry workers. Indonesian Journal of Medical Laboratory Science and Tecnology. 2013;53(9):1689–99.
44. Lastri P, Dewata I, Sari M. The relationship between work period and use of personal protective equipment with respiratory disorder complaints in brick craftsman in Sintuk Toboh Gadang District Padang Pariaman Regency 2017. IOP Conf Ser Earth Environ Sci. 2019;314:6.
45. Wcherrie J, Apsley A, Cowie H, Steinle S, Mueller W, Lin C, et al. Effectiveness of face masks used to protect Beijing residents against particulate air pollution. Occup Environ

Med. 2018;75(6):446–52.
46. Robson AL, Stephenson C, Schulte P, Amick B, Chan S, Clarke J, et al. A systematic review of the effectiveness of training & education for the protection of workers. Institute for Work & Health. 2010;1–148.
47. Robson LS, Stephenson CM, Schulte PA, Amick BC, Irvin EL, Eggerth DE, et al. A systematic review of the effectiveness of occupational health and safety training. Scand J Work Environ Health. 2012; 38: 193–208.
48. Cohen A, Colligan MJ, Sinclair R, Newman J, Schuler R. Assessing occupational safety and health training: A literature review. Cincinnati, OH Natl Institutes Heal. 1998;1–174.

CHAPTER 7

EXPOSURE-RESPONSE RELATIONSHIPS FOR WOOD DUST EXPOSURE AND ASTHMA AMONG WORKERS IN THE MOZAMBIQUAN WOOD PROCESSING INDUSTRY

ABSTRACT

Background: Despite the various studies exploring dose response relationships in wood workers, few studies have undertaken a comprehensive approach using multiple exposure indices in relation to work-related asthma among workers exposed to specific tropical woods to evaluate multiple clinical endpoints for work-related asthma. The aim of this current study was to explore the nature of the exposure-response relationships between inhalable particulate wood dust exposure using multiple exposure metrics (current and cumulative exposure) and multiple clinical indices of work-related asthma (respiratory symptoms, airway obstruction, bronchial reversibility and exhaled nitric oxide) among workers in the Mozambiquan wood processing industry.

Methods: A cross-sectional study of 450 wood processing workers was conducted in three provinces of Mozambique.Exposure metrics were derived from 124 personal inhalable dust particulate samples collected during the environmental exposure assessment, supplemented by data obtained from the ECRHS questionnaire. The main exposure metrics of interest were current inhalable dust particulate exposure concentrations and cumulative exposure based on the employment duration within the current factory. Both unadjusted and adjusted (age, gender, atopy, smoking) multivariate linear and logistic regression models were developed in relation to the clinical outcomes of interest.

Results: Work related ocular-nasal symptoms were significantly associated with current inhalable dust exposures, using both jobs (medium exposure category OR= 3.31, 95% CI: 1.09 – 10.00; high exposure category OR= 4.67, 95% CI: 1.42 – 15.35) and actual dust levels (medium exposure category OR= 3.45, 95% CI: 1.21 – 10.63; high exposure category OR= 3.66, 95% CI: 1.19 – 11.26) in a dose-dependent manner in unadjusted models. A similar trend was observed in the adjusted models with at least a two to three-fold increase in risk. Work related ocular-nasal symptoms were negatively associated with cumulative exposure, in both the current job (OR= 0.42, 95% CI: 0.21 – 0.82) as well as over all jobs (OR= 0.40, 95% CI: 0.21 – 0.76). Work-related asthma symptoms were positively associated with mean cumulative dust exposure based on current (OR= 1.01, 95% CI: 1.00 – 1.01) as well as all jobs held in the factory (OR= 1.01, 95% CI: 1.00 – 1.01). In both unadjusted and adjusted models increasing degree of bronchial reversibility was associated with increasing current dust exposures using metrics based on job titles (medium exposure category OR= 1.84, 95% CI: 1.23 – 2.72; high exposure category OR= 1.60, 95% CI: 1.02 – 2.51) as well as actual inhalable dust levels (medium exposure category OR= 1.92, 95% CI: 1.27 – 2.86; high exposure category OR= 1.67,

95% CI: 1.11 – 2.51).In both unadjusted and adjusted models increasing FeNO was associated with cumulative dust exposure in current job (quartile 2, OR= 1.23, 95% CI: 1.02 – 1.51; quartile 4, OR= 1.23, 95% CI: 1.02 – 1.49) as well across all jobs in the factory (quartile 4, OR= 1.22, 95% CI: 1.01 – 1.48).

Conclusion: The findings of this study has demonstrated positive exposure-response relationships between inhalable particulate wood dust exposures generated during work activities and work-related ocular-nasal symptoms and asthma of a more acute irritant nature and associated with possible chronic airway inflammation. The findings complement the existing evidence confirming the association between wood dust exposures and asthma and provide better insights into its phenotypic manifestations in the workplace setting.

7.1 INTRODUCTION

There have been an increasing number of epidemiological studies in the past decade that have reported an association between wood dust exposure levels and adverse respiratory health outcomes.

The evidence for the association between wood dust exposure and the risk of asthma in particular was demonstrated in the meta-analysis conducted by Pérez-Ríos et al. (1). Earlier studies by Schlünssen et al. (2) in Danish woodworkers, demonstrated that the prevalence of asthma and rhinitis increased with increasing levels of exposure. Later studies among female woodworkers exposed to dry wood also demonstrated a dose-dependent increase in the cumulative incidence of respiratory symptoms in relation to baseline wood dust levels (3). Schlünssen et al, have also shown that work-related asthma symptoms as well as symptomatic bronchial hyperresponsiveness is related to wood dust in a dose dependent manner (4).
In the recent ECRHS study of occupational exposures over a 20-year period, Lytras et al. (5), demonstrated that the incidence of COPD increases with increasing of level of exposure.

However, there have been studies that were not able to demonstrate convincing exposure relationships. An earlier Finish register-based population study was unable to report such an association since the incidence rates for asthma were significantly increased in both woodworkers and blue-collar workers in wood industries, without a clear dose-response relationship (6). In a Tanzanian study of small scale wood industries (7), despite the high prevalence of respiratory symptoms in exposed workers, the investigators were unable to demonstrate significant exposure-response relationships. Furthermore, in studies of British woodworkers (8) and Thai rubber wood sawmill factory workers (9) no clear relationships between wood dust exposure and either respiratory symptoms or lung function could be demonstrated.

It is evident that the nature of the exposure-response relationships for wood dust exposure and adverse respiratory outcomes have focused mainly on the relationship between currentexposures and either respiratory symptoms, work-related asthma symptoms or lung function (5,6,7, 10,11,12,13). Some studies have also demonstrated that level of bronchial responsiveness in wood workers increased significantly with increasing intensity of current exposure (4, 10). Atopic status has been shown to modify the relationship between asthma risk and increasing wood dust levels (4, 14). However, while there has been one study that has explored the association between airborne wood dust concentration levels and the prevalence of specific IgE to particular wood species, there have not been any studies that have investigated the association between airborne allergen levels and specific allergic sensitization among wood-workers (15,16). There have been some studies that have also observed a dose-response relationships between cumulative wood dust exposure and annual decline in lung function parameters (10, 11,12, 17) and new-onset chronic obstructive pulmonary disease (COPD) in women (13).

Despite the various studies exploring dose response relationships in wood workers, few studies have undertaken a comprehensive approach using multiple exposure indices in relation to work-related asthma among workers exposed to specific tropical woods used in the Mozambique wood processing industry. Furthermore, in addition to the traditional approaches in assessing work-related asthma in resource constrained settings, more recent studies have suggested the use of a broader repertoire of asthma indices to characterise different asthma phenotypes, including the use of other definitions of bronchial reversibility (to overcome the influence of age, sex, height and level of airway obstruction on the appropriate cut-off for differentiating asthma from normal healthy subjects) as well as identifying the presence of underlying airway inflammation present in asthma (17, 18).

The aim of this current study was to explore the nature of the exposure-response relationships between inhalable particulate wood dust exposure using multiple exposure metrics (current and cumulative exposure) and multiple clinical indices of work-related asthma (respiratory symptoms, airway obstruction, bronchial reversibility and fractional exhaled nitric oxide) among workers in the Mozambiquan wood processing industry.

7.2 METHODS

7.2.1 EXPOSURE ASSESSMENT

Exposure metrics were derived from 124 personal inhalable dust particulate samples collected during the environmental exposure assessment as previously described (chapter 4). During the exposure assessment information on job titles were collected. Data on employment duration in the current factory the current job (in years) as reported in the questionnaire (see next section) was used to develop the exposure metrics for the exposure-response analysis.

7.2.2 HEALTH OUTCOME ASSESSMENT

Data from the cross-sectional epidemiological study of 450 workers employed in 6 factories in three major sites (Maputo City, Maputo province and Sofala Province) in Mozambique was used for this aspect of the study. Those who agreed to participate underwent health outcome assessments that were conducted at the work site during work time, which are briefly described below.

7.2.2.1 Questionnaire

Each worker completed a standard interviewer-administered questionnaire of the European Community Respiratory Health Survey (ECRHS) for the investigation of asthma. The questionnaire was modified to include questions relating to current and previous employment, exposure to wood dust, types of wood the worker is exposed to, information regarding the origin of the wood species processed, as well as chemical and pesticide treatment of the woods. The questionnaire was translated into Portuguese and back translated to English to verify translation correctness.

7.2.2.2 Test for atopy (Phadiatop)

Serum samples were collected from 391 participants to assess for the presence of atopy. The blood was allowed to clot for 1-2 hours at room temperature (20-24 degrees Celsius) and then centrifuged at 1350 rpm for 10 minutes at room temperature prior to being stored at -80 degrees Celsius. The Phadiatop analysis was performed by the SANAS accredited (ISO 15189:2007), National Institute for Occupational Health (NIOH) Immunology laboratory.

7.2.2.3 Spirometry and post-bronchodilator response (PBR)

Overall, there were 443 participants that performed pre-bronchodilator and 431 participants post-bronchodilator spirometry. There were 12 workers whose spirometry outputs were graded as “F” according to the EasyOne spirometer. Details of the spirometry method have been described earlier. In brief, the EasyOne spirometer was used according to the American Thoracic Society (ATS)/ERS guidelines for conducting spirometry (19).The timing of spirometry was during the working week. Special instructions to workers to ensure that tested individuals did not smoke tobacco (at least 2 hours before) nor did they take any anti-asthmatic inhalers (12 hours before) or oral asthma medications (48 hours before) prior to the test. The results of spirometry and BDR tests were recorded on lung function test data collection sheets and were graded for acceptability prior to being used in the statistical analysis.

7.2.2.4 Fractional Exhaled Nitric Oxide (FeNO)

A total of 443 workers underwent FeNO measurements using ATS/ERS recommendations for standardized procedures for the measurement of exhaled nitric oxide levels (20). A hand-held portable nitric oxide sampling device (NIOX MINO® Airway Inflammation Monitor (NIOX MINO); Aerocrine AB, Solna, Sweden) was used. The worker was seated comfortably, with the mouthpiece at the proper height and position. A nose clip was not used, as this may allow nasal NO to accumulate and promote leakage of this NO via the posterior nasopharynx. The worker inserted a mouthpiece and inhaled over 2 to 3 seconds through the mouth to total lung capacity (TLC), and then exhaled immediately, since breath holding could affect FeNO. Two technically adequate measurements were performed. If the measurements differed by 10ppb or more, a third measurement was performed and the mean of all three measurements was used. The test was performed during the work shift prior to spirometry.

7.2.3 STATISTICAL ANALYSIS

a) Operational definitions of exposure variables

Exposure levels were assigned to all workers based on environmental exposure assessment for wood dust particulate concentrations obtained for each job during the exposure assessment sampling. Both continuous and categorical current exposure metrics were used.

Current wood dust particulate exposures were defined based two exposure parameters:
- *current exposure category based on current job titles:* maintenance and upholsterer were regarded as the low exposure category; machine operators, painter-varnishers and assemblers

were classified in the medium exposure category; and planers, sanders, sawyers and carvers in the high exposure category.

- *current exposure category based on tertile inhalable dust levels*: exposure was categorized as low exposure category (<4.68 mg/m^3), medium exposure category (4.68-4.71 mg/m^3) and high exposure category (>4.71 mg/m^3).

Cumulative wood dust particulate exposures were defined based two exposure parameters:
- *cumulative dust exposure based on current job* in the factory: was calculated as average inhalable dust concentration for the current job x employment duration in factory.
- *cumulative dust exposure based on all jobs in the factory:* was calculated as sum total of the (average inhalable dust particulate concentration for each job x employment duration for each job) across all jobs within the factory.

Categorical exposure metrics for cumulative exposure used quartiles, with the lowest quartile as the reference category.

b) Operational definitions of outcomes variables

An *asthma symptom score* was computed based on the sum of answers (0=no, 1=yes) to five questions reported in the past 12 months. These included the presence of shortness of breath while wheezing; being woken up with chest tightness; an attack of shortness of breath at rest; an attack of shortness of breath after exercise; and being woken up by an attack of shortness of breath. A binary variable was created from these five asthma-related symptoms (≥ 2 symptoms vs 0-1 symptom). Having ≥ 2 asthma-related symptoms was considered ‘more symptomatic’ and 0-1 symptom as ‘less symptomatic’.

Work-related asthma symptoms and *work-related ocular–nasal symptoms* were defined as symptoms (chest/ocular-nasal) experienced at any time during their work. A more specific variable for both these outcomes was defined as symptoms (either chest/ocular-nasal) experienced at work that improved when away from work.

The presence of *atopy* was defined as sensitization to common aeroallergens (house dust mites, grass pollens, cat, dog, and cockroach) as determined by a positive Phadiatop® test (Phadia AB, Uppsala, Sweden), classified as any value ≥0.35ku/L.

Both *baseline obstruction* (FEV_1/FVC < 70%) as well as *fixed airway obstruction* defined as FEV_1/FVC < 70% without improvement after bronchodilator administration was used, while *bronchial reversibility* was measured in two ways: i) as ≥12% and ≥200 ml FEV_1 increase post-bronchodilator and as ii) ≥9% FEV_1 increase post-bronchodilator as a proportion of FEV_1 % predicted.

FeNO results were interpreted as being i) low for values < 25ppb; ii) elevated for values 25 - 50ppb; and iii) high for values > 50ppb. A FeNO level > 50 ppb in the absence of a recent upper respiratory tract infectionis generally considered to indicate the presence of eosinophilic airway inflammation associated with allergic asthma (21, 22).

c) Exposure-response modelling

All analyses were conducted using STATA version 12 software. Since there were no exposure measurements for non-wood processing workers (e.g. forestry, office, warehouse etc.), it was not possible to assign exposures to these workers, and they were therefore excluded from the exposure-response analysis. The exposure estimates were therefore available on 308 workers based on their current job and for 336 workers for cumulative exposure across all jobs within the factory. Continuous indices of FeNO and post-bronchodilator FEV_1 were log transformed (natural log) prior to conducting linear regression analysis and results were reported as geometric mean ratios with confidence intervals. Unadjusted logistic and linear regression models were performed to explore the association between asthma health outcomes (e.g. asthma symptom score, work-related ocular nasal symptoms, work-related asthma symptoms, fixed airway obstruction, bronchial reversibility, FeNO ≥ 50 ppb) and dust exposure variables (e.g. current exposure categories, current exposure concentrations, cumulative exposure concentrations). Multivariate logistic and linear regression saturated models were developed that were adjusted for age, gender and smoking status.

7.3 RESULTS

7.3.1 Association between current and cumulative particulate dust exposure in relation to work-related respiratory symptoms based on unadjusted regression models

Work related ocular-nasal symptoms were significantly associated with current inhalable dust exposures, based on either job category (medium: OR= 3.31, 95% CI: 1.09 – 10.00; high: OR= 4.67, 95% CI: 1.42 – 15.35); as well as actual dust levels (medium: OR= 3.45, 95% CI: 1.21 – 10.63; high: OR=3.66, 95% CI: 1.19 – 11.26) in a dose-dependent manner (Table 7.1a).

Surprisingly, work related ocular-nasal symptoms were negatively associated with cumulative exposure, using either current job (OR= 0.42, 95% CI: 0.21 – 0.82) as well asoverall jobs (OR= 0.40, 95% CI: 0.21 – 0.76) (Table 7.1b). On the other hand,work-related asthma symptoms were positively associated with mean cumulative dust exposure based on current (OR= 1.01, 95% CI: 1.00 – 1.01) as well as over all jobs (OR= 1.01, 95% CI: 1.00 – 1.01) held in the factory. A consistent dose-response trend was observed using all jobs (quartile 2, OR= 1.00, 95 CI:0.39 – 2.54; quartile 3, OR= 1.20, 95% CI: 0.49 – 2.95; quartile 4, OR= 1.94, 95% CI: 0.83 – 4.52), although not statistically significant.

Table 7.1a: Association between work-related respiratory symptoms and current inhalable particulate dust exposure among wood processing workers in Mozambique based on unadjusted regression models

	Prevalence n (%)	**Asthma symptom score (≥2 vs 0-1)**	**Work-related ocular nasal symptoms (ever)[a]**	**Work-related ocular nasal symptoms[b]**	**Work-related asthma symptoms (ever)[a]**	**Work-related asthma symptoms[b]**
Prevalence: n (%)		45 (10%)	182 (40)	88 (20)	65 (14)	36 (8)
Mean current inhalable dust concentration (mg/m^3)		0.96 (0.79 – 1.18)	1.11 (0.99 – 1.24)	1.08 (0.94 – 1.26)	1.09 (0.94 – 1.27)	0.97 (0.79 – 1.18)
Current exposure categories based on current job titles						
Low (maintenance, upholsterer)	24 (8)	1	1	1	1	1
Medium (machine operator, painter-varnisher, assembler)	226 (73)	2.48 (0.24 – 19.26)	**3.31 (1.09 – 10.00)***	1.28 (0.36 – 4.53)	1.15 (0.33 – 4.10)	2.61 (0.34 – 20.20)
High (planer, sander, sawyer, carver)	58 (19)	2.17 (0.24 – 19.62)	**4.67 (1.42 – 15.35)***	2.02 (0.52 – 7.86)	1.83 (0.47 – 7.16)	1.70 (0.18 – 16.08)
Current exposure categories based on dust levels						
Low (<4.68 mg/m^3)	24 (8)	1	1	1	1	1
Medium (4.68-4.71 mg/m^3)	142 (46)	2.12 (0.26 – 17.12)	**3.45 (1.21 – 10.63)***	1.21 (0.33 – 4.44)	1.35 (0.37 – 4.91)	3.34 (0.42 – 26.25)
High (>4.71 mg/m^3)	142 (46)	2.72 (0.34 – 21.58)	**3.66 (1.19 – 11.26)***	1.64 (0.46 – 5.91)	1.21 (0.33 – 4.44)	1.56 (0.19 – 12.87)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Asthma symptom score: short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath
[a]Symptoms (ocular-nasal/chest) ever experienced at work; [b]Symptoms (ocular-nasal/chest) ever experienced at work that improves when away from work
Each OR represents a separate unadjusted regression model

Table 7.1b: Association between work-related respiratory symptoms and cumulative inhalable dust exposure among wood processing workers in Mozambique based on unadjusted regression models

	Prevalence n (%)	Asthma symptom score (≥2 vs 0-1)	Work-related ocular nasal symptoms (ever)[a]	Work-related ocular nasal symptoms[b]	Work-related asthma symptoms (ever)[a]	Work-related asthma symptoms[b]
Prevalence: n (%)		45 (10%)	182 (40)	88 (20)	65 (14)	36 (8)
Mean cumulative exposure based on current job in the factory(mg/m^3-yr)		1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	**1.01 (1.00 – 1.01)****	1.00 (0.99 – 1.01)
Mean cumulative exposure based on all jobs in the factory(mg/m^3-yr)		1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	**1.01 (1.00 – 1.01)***	1.00 (0.99 – 1.01)
Cumulative exposure based on current job						
Quartile 1 <=10.09 (mg/m^3-yr)	82 (27)	1	**1**	1	1	1
Quartile 2 >10.09 and <=31.335 (mg/m^3-yr)	72 (23)	0.75 (0.20 – 2.75)	**0.42 (0.21 – 0.82)***	0.72 (0.30 – 1.72)	0.73 (0.28 – 1.90)	1.15 (0.32 – 4.14)
Quartile 3 >31.335 and <=61.035 (mg/m^3-yr)	77 (25)	1.89 (0.65 – 5.48)	0.82 (0.44 – 1.54)	0.91 (0.40 – 2.06)	0.68 (0.26 – 1.76)	2.30 (0.75 – 7.06)
Quartile 4 >61.035 (mg/ m^3 -yr)	77 (25)	1.47 (0.49 – 4.45)	0.87 (0.46 – 1.62)	0.91 (0.40 – 2.06)	1.91 (0.86 – 4.26)	1.79 (0.56 – 5.72)
Cumulative exposure overall all jobs						
Quartile 1 <=9.405 (mg/m^3-yr)	84 (25)	1	1	1	1	1
Quartile 2 >9.405 and < =27.94 (mg/m^3-yr)	84 (25)	1.00 (0.31 – 3.24)	**0.40 (0.21 – 0.76)****	0.92 (0.41 – 2.05)	1.00 (0.39 – 2.54)	1.18 (0.38 – 3.68)
Quartile 3 >27.94 and <=60.54 (mg/m^3-yr)	86 (26)	1.52 (0.52 – 4.47)	0.69 (0.37 – 1.26)	1.05 (0.48 – 2.29)	1.20 (0.49 – 2.95)	0.98 (0.30 – 3.15)
Quartile 4 >60.54(mg/m^3-yr)	82 (24)	1.41 (0.47 – 4.42)	0.71 (0.38 – 1.31)	0.95 (0.42 – 2.11)	1.94 (0.83 – 4.52)	1.60 (0.54 – 4.73)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Asthma symptom score: short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath
[a]Symptoms (ocular-nasal/chest) ever experienced at work; [b]Symptoms (ocular-nasal/chest) ever experienced at work that improves when away from work
Each OR represents a separate unadjusted regression model

7.3.2 Association between current and cumulative dust exposure in relation to lung function indices and airway obstruction based on unadjusted regression models

Increasing mean current inhalable dust concentrations were positively associated with the baseline FEV_1/FVC ratio (OR= 1.01, 95% CI: 1.00 – 1.02) (Table 7.2a). For cumulative exposure a negative trend was observed between cumulative dust exposure based on current job and the post bronchodilator FEV_1/FVC ratio in a dose dependent manner (quartile 2, OR= 0.99, 95% CI: 0.94 – 1.03; quartile 3, OR= 0.97, 95% CI: 0.93 – 1.01; OR=0.96, 95% CI:0.91 – 0.99) (Table 7.2b). However, the relationship was not statistically significant across all quartiles.

7.3.3 Association between current and cumulative inhalable dust exposures in relation to airway reversibility based on unadjusted regression models

Increasing level of bronchial reversibility (as a percentage of FEV_1 predicted) was associated with current dust exposures based on job titles (medium exposure category: OR= 1.84, 95% CI: 1.23 – 2.72; high exposure category: OR= 1.60, 95% CI: 1.02 – 2.51) as well as actual dust levels (medium exposure category: OR= 1.92, 95% CI: 1.27 – 2.86; high exposure category: OR= 1.67, 95% CI: 1.11 – 2.51) (Table 7.3a). Significant bronchial reversibility was also associated with cumulative exposure index calculated across all jobs (OR=1.01, 95%CI: 1.00 – 1.02) (Table 7.3b). However, this trend was not observed for cumulative dust exposure categories.

Table 7.2a: Association between current inhalable dust exposure in relation to lung function indices of airway obstruction among wood processing workers in Mozambique based on unadjusted regression models

	Prevalence n (%)	Baseline FEV_1/FVC	Baseline FEV_1/FVC <0.7	PBD FEV_1/FVC	PBD FEV_1/FVC <0.7
Prevalence: n (%)		-	83 (19)	-	58 (14)
Mean current dust concentration (mg/m^3)		**1.01 (1.00 – 1.02)***	0.98 (0.84 – 1.13)	1.01 (0.99 – 1.01)	0.93 (0.78 – 1.11)
Current exposure categories based on current job titles					
Low (maintenance, upholsterer)	24 (8)	1	1	1	1
Medium (machine operator, painter-varnisher, assembler)	226 (73)	1.04 (0.98 – 1.09)	0.85 (0.30 – 2.41)	1.03 (0.98 – 1.09)	0.72 (0.23 – 2.27)
High (planer, sander, sawyer, carver)	58 (19)	1.06 (0.99 – 1.13)	0.81 (0.24 – 2.68)	1.04 (0.98 – 1.12)	0.58 (0.15 – 2.29)
Current exposure categories based on inhalable dust levels					
Low (<4.68 mg/m^3)	24 (8)	1	1	1	1
Medium (4.68-4.71 mg/m^3)	142 (46)	1.03 (0.97 – 1.08)	0.86 (0.29 – 2.51)	1.03 (0.98 – 1.09)	0.68 (0.21 – 2.25)
High (>4.71 mg/m^3)	142 (46)	1.05 (0.99 – 1.12)	0.83 (0.28 – 2.42)	1.04 (0.98 – 1.11)	0.70 (0.21 – 2.29)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Fixed airway obstruction: PBD (post-bronchodilator) FEV_1/FVC < 70%
Each OR represents a separate unadjusted regression model

Table 7.2b: Association between cumulative inhalable dust exposure in relation to lung function indices of airway obstruction among wood processing workers in Mozambique based on unadjusted regression models

	Prevalence n (%)	Baseline FEV_1/FVC	Baseline FEV_1/FVC <0.7	PBD FEV_1/FVC	PBD FEV_1/FVC <0.7
Prevalence: n (%)		-	83 (19)	-	58 (14)
Crude overall cumulative exposure in the factory (mg/m^3- yr)		0.99 (0.99 – 1.00)	1.00 (0.99 – 1.01)	0.99 (0.99 – 1.00)	1.00 (0.99 – 1.01)
Crude overall cumulative exposure over all the jobs (mg/m^3- yr)		0.99 (0.99 – 1.00)	1.00 (0.99 – 1.01)	0.99 (0.99 – 1.00)	1.00 (0.99 – 1.01)
Cumulative exposure based on current job					
Quartile 1 <=10.09 (mg/m^3-yr)	82 (27)	1	1	1	1
Quartile 2 >10.09 and <=31.335 (mg/m^3-yr)	72 (23)	1.02 (0.98 – 1.06)	1.34 (0.55 – 3.25)	0.99 (0.94 – 1.03)	1.52 (0.54 – 4.24)
Quartile 3 >31.335 and <=61.035 (mg/m^3-yr)	77 (25)	0.99 (0.95 – 1.03)	1.81 (0.78 – 4.21)	0.97 (0.93 – 1.01)	1.50 (0.54 – 4.17)
Quartile 4 >61.035 (mg/ m^3 -yr)	77 (25)	0.99 (0.94 – 1.03)	1.75 (0.75 – 4.06)	**0.96 (0.91 – 0.99)***	1.67 (0.61 – 4.59)
Cumulative exposure overall all jobs					
Quartile 1 <= 9.405 (mg/m^3-yr)	84 (25)	1	1	1	1
Quartile 2 > 9.405 and < =27.94 (mg/m^3-yr)	84 (25)	1.01 (0.97 – 1.04)	1.12 (0.49 – 2.57)	0.97 (0.93 – 1.01)	2.11 (0.80 – 5.62)
Quartile 3 > 27.94 and <= 60.54 (mg/m^3-yr)	86 (26)	1.00 (0.96 – 1.04)	1.12 (0.49 – 2.57)	0.98 (0.94 – 1.02)	1.14 (0.39 – 3.31)
Quartile 4 > 60.54(mg/m^3-yr)	82 (24)	0.99 (0.95 – 1.03)	1.37 (0.61 – 3.06)	**0.96 (0.92 – 0.99)***	1.92 (0.71 – 5.17)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Fixed airway obstruction: PBD (post-bronchodilator) FEV_1/FVC < 70%
Each OR represents a separate unadjusted regression model

Table 7.3a: Association between current inhalable dust exposures in relation to airway reversibility among wood processing workers in Mozambique in based on unadjusted regression models

	Prevalence n (%)	FEV_1 (ln) PBD increase (%)	FEV_1 (ln) PBD increase (% pred)	PBD ΔFEV1% ≥ 9% of predicted FEV_1	PBD ≥12% and ≥ 200 ml FEV_1 increase
Prevalence: n (%)		-	-	24 (6)	14 (3)
Mean current dust concentration (mg/m^3)		1.01 (0.95 -1.07)	1.01 (0.96 – 1.07)	0.93 (0.71 – 1.21)	1.01 (0.74 – 1.39)
Current exposure categories based on current job titles					
Low (maintenance, upholsterer)	24 (8)	1	1	1	1
Medium (machine operator, painter-varnisher, assembler)	226 (73)	**1.82 (1.19 – 2.80)****	**1.84 (1.23 – 2.72)****	NC	NC
High (planer, sander, sawyer, carver)	58 (19)	1.57 (0.96 – 2.53)	**1.60 (1.02 – 2.51)***	NC	NC
Current exposure categories based on dust levels					
Low (<4.68 mg/m^3)	24 (8)	1	1	1	1
Medium (4.68-4.71 mg/m^3)	142 (46)	**1.89 (1.22 – 2.94)****	**1.92 (1.27 – 2.86)****	NC	NC
High (>4.71 mg/m^3)	142 (46)	**1.63 (1.05 – 2.53)***	**1.67 (1.11 – 2.51)***	NC	NC

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Airway reversibility: ≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD ΔFEV_1% ≥9% of the predicted FEV_1
Each OR represents a separate unadjusted regression model
NC: not calculable

Table 7.3b: Association between cumulative inhalable dust exposures in relation to airway reversibility among wood processing workers in Mozambique based on unadjusted regression models

	Prevalence n (%)	FEV_1 (ln) PBD increase (%)	FEV_1 (ln) PBD increase (% pred)	PBD ΔFEV1% ≥ 9% of predicted FEV_1	PBD ≥ 12% and ≥ 200 ml FEV_1 increase
Prevalence: n (%)		-	-	24 (6)	14 (3)
Mean cumulative exposure based on current job in the factory (mg/m^3-yr)		1.00 (1.00 – 1.00)	1.00 (1.00 – 1.00)	1.00 (0.99 – 1.01)	1.01 (0.99 – 1.02)
Mean cumulative exposure based on all jobs in the factory (mg/m^3-yr)		1.00 (1.00 – 1.00)	1.00 (0.99 – 1.00)	1.00 (0.99 – 1.01)	**1.01 (1.00 – 1.02)***
Cumulative exposure based on current job					
Quartile 1 <=10.09 (mg/m^3-yr)	82 (27)	1	1	1	1
Quartile 2 >10.09 and <=31.335 (mg/m^3-yr)	72 (23)	0.74 (0.53 – 1.03)	0.77 (0.57 – 1.05)	1.21 (0.29 – 5.04)	NC
Quartile 3 >31.335 and <=61.035 (mg/m^3-yr)	77 (25)	0.88 (0.64 – 1.22)	0.89 (0.66 – 1.20)	1.38 (0.36 – 5.35)	0.71 (0.12 – 4.40)
Quartile 4 >61.035 (mg/ m^3 -yr)	77 (25)	0.88 (0.64 – 1.21)	0.87 (0.65 – 1.17)	0.80 (0.17 – 3.72)	1.86 (0.43 – 8.09)
Cumulative exposure overall all jobs					
Quartile 1 <= 9.405 (mg/m^3-yr)	84 (25)	1	1	1	1
Quartile 2 > 9.405 and < =27.94 (mg/m^3-yr)	84 (25)	1.03 (0.75 – 1.40)	1.04 (0.78 (1.39)	1.41 (0.30 – 6.49)	0.51 (0.05 – 5.77)
Quartile 3 > 27.94 and <= 60.54 (mg/m^3-yr)	86 (26)	1.01 (0.74 – 1.36)	1.01 (0.76 – 1.34)	2.05 (0.50 – 8.50)	0.99 (0.14 – 7.18)
Quartile 4 > 60.54 (mg/m^3-yr)	82 (24)	1.01 (0.74 – 1.38)	0.99 (0.74 – 1.32)	1.04 (0.20 – 5.32)	2.71 (0.51 – 14.38)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Airway reversibility: ≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD ΔFEV_1% ≥9% of the predicted FEV_1
Each OR represents a separate unadjusted regression model
NC: not calculable

7.3.4 Association between current and cumulative dust exposure and exhaled nitric oxide (FeNO) based on unadjusted regression models

There was no statistically significant associations between FeNO and current inhalable dust particualate exposures. However, increasing FeNO was associated with cumulative dust exposure based on current job (quartile 2, OR= 1.23, 95% CI: 1.02 – 1.51; quartile 4, OR= 1.23, 95% CI: 1.02 – 1.49) as well across all jobs in the factory (quartile 4, OR= 1.22, 95% CI: 1.01 – 1.48) (Table 7.4b). When higher cut-off for FeNO>50ppb, indicative of allergic airway inflammation, much higher odds ratios were observed, but were not statistically significant.

Table 7.4a: Association between current inhalable dust exposure and exhaled nitric oxide (FeNO) among wood processing workers in Mozambique based on unadjusted regression models

	Prevalence n (%)	FeNO (ln), ppb	FeNO ≥ 25 ppb	FeNO ≥ 50 ppb	FeNO 25-50 ppb vs FeNO <25 ppb	FeNO >50 ppb vs FeNO <25 ppb
Prevalence: n (%)		-	126 (28)	22 (5)	104 (23)	22 (5)
Mean current dust concentration (mg/m^3)		1.00 (0.96 – 1.03)	0.92 (0.81 – 1.04)	1.12 (0.89 – 1.39)	0.88 (0.76 – 1.01)	1.08 (0.86 – 1.36)
Current exposure categories based on current job titles						
Low (maintenance, upholsterer)	24 (8)	1	1	1	1	1
Medium (machine operator, painter-varnisher, assembler)	226 (73)	1.14 (0.88 – 1.48)	1.26 (0.50 – 3.16)	1.42 (0.18 – 11.39)	1.21 (0.46 – 3.22)	1.50 (0.19 – 12.22)
High (planer, sander, sawyer, carver)	58 (19)	1.08 (0.81 – 1.46)	0.77 (0.27 – 2.24)	1.70 (0.18 – 16.08)	0.64 (0.20 – 2.05)	1.55 (0.16 – 14.83)
Current exposure categories based on dust levels						
Low (<4.68 mg/m^3)	24 (8)	1	1	1	1	1
Medium (4.68-4.71 mg/m^3)	142 (46)	1.16 (0.89 – 1.52)	1.39 (0.54 – 3.38)	1.77 (0.22 – 14.49)	1.31 (0.48 – 3.55)	1.91 (0.23 – 15.91)
High (>4.71 mg/m^3)	142 (46)	1.09 (0.84 – 1.43)	0.93 (0.36 – 2.41)	1.20 (0.14 – 10.23)	0.89 (0.32 – 2.45)	1.17 (0.13 – 10.09)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
FeNO (ln): Fractional exhaled nitric oxide (natural log)
Each OR represents a separate unadjusted regression model

Table 7.4b: Association between cumulative inhalable dust exposure and exhaled nitric oxide (FeNO) among wood processing workers in Mozambique based on unadjusted regression models

	Prevalence n (%)	FeNO (ln), ppb	FeNO ≥ 25 ppb	FeNO ≥ 50 ppb	FeNO 25-50 ppb vs FeNO <25 ppb	FeNO >50 ppb vs FeNO <25 ppb
Prevalence: n (%)		-	126 (28)	22 (5)	104 (23)	22 (5)
Mean cumulative exposure based on current job in the factory (mg/m^3-yr)		1.00 (0.99 – 1.00)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)
Mean cumulative exposure based on all jobs in the factory (mg/m^3-yr)		1.00 (0.99 – 1.00)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	1.01 (1.00 – 1.01)	1.00 (0.99 – 1.01)
Cumulative exposure based on current job						
Quartile 1 <=10.09 (mg/m^3-yr)	82 (27)	1	1	1	1	1
Quartile 2 >10.09 and <=31.335 (mg/m^3-yr)	72 (23)	**1.23 (1.02 – 1.51)***	1.43 (0.71 – 2.86)	4.38 (0.88 – 21.79)	1.16 (0.55 – 2.45)	3.84 (0.76 – 19.35)
Quartile 3 >31.335 and <=61.035 (mg/m^3-yr)	77 (25)	1.11 (0.91 – 1.35)	1.14 (0.56 – 2.32)	2.82 (0.53 – 14.97)	0.98 (0.46 – 2.10)	2.59 (0.48 – 13.94)
Quartile 4 >61.035 (mg/ m^3 -yr)	77 (25)	**1.23 (1.02 – 1.49)***	1.73 (0.87 – 3.44)	2.22 (0.40 – 12.50)	1.65 (0.81 – 3.40)	2.38 (0.42 -13.59)
Cumulative exposure overall all jobs						
Quartile 1 <= 9.405 (mg/m^3-yr)	84 (25)	1	1	1	1	1
Quartile 2 > 9.405 and < =27.94 (mg/m^3-yr)	84 (25)	1.16 (0.96 – 1.39)	1.29 (0.66 – 2.52)	2.10 (0.51 – 8.71)	1.14 (0.56 – 2.36)	2.18 (0.52 – 9.11)
Quartile 3 > 27.94 and <= 60.54 (mg/m^3-yr)	86 (26)	1.07 (0.90 – 1.30)	1.11 (0.56 – 2.18)	2.05 (0.50 – 8.48)	0.96 (0.46 – 2.01)	2.03 (0.49 – 8.50)
Quartile 4 > 60.54(mg/m^3-yr)	82 (24)	**1.22 (1.01 – 1.48)***	1.66 (0.85 – 3.22)	1.04 (0.20 – 5.30)	1.73 (0.86 – 3.46)	1.22 (0.24 – 6.28)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
FeNO (ln): Fractional exhaled nitric oxide (natural log)
Each OR represents a separate unadjusted regression model

7.3.5 Association between work-related respiratory symptoms and current as well as cumulative dust exposure based on multivariate regression models

In the adjusted models current exposure was associated with a three to four-fold increase in risk of development work related ocular-nasal symptoms (Table 7.5a). However, not all categories were statistically significant. A history of work-related asthma symptoms was positively associated with mean cumulative dust exposure based on the current job (OR= 1.01, 95% CI: 1.00 – 1.02) (Table 7.5b).

7.3.6 Association between current and cumulative dust exposure in relation to lung function indices and airway obstruction based on multivariate regression models

In the adjusted models no associations between current and cumulative exposure andbaseline FEV_1/FVC ratio was observed (Table 7.6a-b).

7.3.7 Association between current and cumulative dust exposures in relation to airway reversibility based on multivariate regression models

In these multivariate models, an increasing level of bronchial reversibility (as a percentage of FEV_1 predicted) was associated with current dust exposures based on job titles (medium exposure category: OR= 1.95, 95% CI: 1.26 – 3.00; high exposed category: OR= 1.72, 95% CI: 1.04 – 2.83) as well as with actual dust levels (medium exposure category: OR= 2.03, 95% CI: 1.31 – 3.16; high exposure category: OR= 1.77, 95% CI: 1.14 – 2.77) (Table 7.7a). A similar pattern was observed for percentage FEV_1 increase. However, no association was observed In relation to cumulative dust exposure (Table 7.7b).

Table 7.5a: Association between work-related respiratory symptoms and current inhalable dust exposure among wood processing workers in Mozambique based on multivariate regression models

	Prevalence n (%)	Asthma symptom score (≥2 vs 0-1)	Work-related ocular nasal symptoms (ever)[a]	Work-related ocular nasal symptoms[b]	Work-related asthma symptoms (ever)[a]	Work-related asthma symptoms[b]
Prevalence: n (%)		45 (10%)	182 (40)	88 (20)	65 (14)	36 (8)
Mean current dust concentration (mg/m^3)		0.95 (0.75 – 1.20)	1.07 (0.94 – 1.23)	1.05 (0.88 – 1.25)	1.15 (0.97 – 1.37)	0.92 (0.73 – 1.16)
Current exposure categories based on current job titles						
Low (maintenance, upholsterer)	24 (8)	1	1	1	1	1
Medium (machine operator, painter-varnisher, assembler)	226 (73)	2.06 (0.26 – 16.40)	3.33 (0.93 – 11.91)	1.49 (0.32 – 6.99)	1.54 (0.33 – 7.11)	1.85 (0.23 – 14.74)
High (planer, sander, sawyer, carver)	58 (19)	1.72 (0.18 – 16.92)	**4.11 (1.03 – 16.37)***	1.72 (0.32– 9.43)	3.05 (0.59 – 15.85)	1.02 (0.10 – 10.82)
Current exposure categories based on dust levels						
Low (<4.68 mg/m^3)	24 (8)	1	1	1	1	1
Medium (4.68-4.71 mg/m^3)	142 (46)	1.83 (0.22 – 15.15)	3.56 (0.98 – 12.99)	1.36 (0.28 – 6.61)	1.79 (0.38 – 8.45)	2.37 (0.29 – 19.20)
High (>4.71 mg/m^3)	142 (46)	2.18 (0.27 – 17.93)	3.32 (0.91 – 12.16)	1.70 (0.35 – 8.21)	1.68 (0.35 – 8.03)	1.07 (0.12 – 9.21)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Asthma symptom score: short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath
[a]Symptoms (ocular-nasal/chest) ever experienced at work; [b]Symptoms (ocular-nasal/chest) ever experienced at work that improves when away from work
Each OR represents a separate adjusted for age, gender, atopy and smoking

Table 7.5b: Association between work-related respiratory symptoms in relation to cumulative inhalable dust exposure among wood processing workers in Mozambique based on multivariate regression models

	Prevalence n (%)	Asthma symptom score (≥2 vs 0-1)	Work-related ocular nasal symptoms (ever)[a]	Work-related ocular nasal symptoms[b]	Work-related asthma symptoms (ever)[a]	Work-related asthma symptoms[b]
Prevalence: n (%)		45 (10%)	182 (40)	88 (20)	65 (14)	36 (8)
Mean cumulative exposure based on current job in the factory(mg/m^3-yr)		1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	**1.01 (1.00 – 1.02)****	1.00 (0.99 – 1.01)
Mean cumulative exposure based on all jobs in the factory(mg/m^3-yr)		1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	1.01 (0.99 – 1.01)	1.01 (0.99 – 1.02)	1.00 (0.99 – 1.01)
Cumulative exposure based on current job						
Quartile 1 <=10.09 (mg/m^3-yr)	82 (27)	1	1	1	1	1
Quartile 2 >10.09 and <=31.335 (mg/m^3-yr)	72 (23)	0.87 (0.22 – 3.45)	0.50 (0.24 – 1.06)	1.23 (0.46 – 3.29)	0.86 (0.31 – 3.37)	1.28 (0.35 – 4.73)
Quartile 3 >31.335 and<=61.035 (mg/m^3-yr)	77 (25)	2.45 (0.75 – 7.95)	1.12 (0.55 – 2.27)	1.49 (0.55 – 4.02)	0.82 (0.29 – 2.30)	2.68 (0.80 – 8.96)
Quartile 4 >61.035 (mg/m^3 -yr.)	77 (25)	2.03 (0.52 – 7.90)	1.66 (0.76 – 3.66)	2.44 (0.81 – 7.32)	2.51 (0.92 – 6.87)	2.70 (0.66 – 11.09)
Cumulative exposure overall all jobs						
Quartile 1 <=9.405 (mg/m^3-yr)	84 (25)	1	1	1	1	1
Quartile 2 >9.405 and < =27.94 (mg/m^3-yr)	84 (25)	1.27 (0.37 – 4.42)	0.50 (0.25 – 1.01)	1.35 (0.53 – 3.42)	0.79 (0.29 – 2.15)	1.38 (0.43 – 4.40)
Quartile 3 >27.94 and <=60.54 (mg/m^3-yr)	86 (26)	1.88 (0.58 – 6.32)	0.97 (0.50 – 1.89)	1.71 (0.68 – 4.28)	1.14 (0.45 – 2.89)	1.20 (0.36 – 4.05)
Quartile 4 >60.54(mg/m^3-yr)	82 (24)	1.71 (0.96 – 1.03)	1.22 (0.59 – 2.55)	2.28 (0.81 – 6.43)	1.80 (0.68 – 4.76)	1.87 (0.51 – 6.95)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Asthma symptom score: short of breath while wheezing, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken up by attack of shortness of breath
[a]Symptoms (ocular-nasal/chest) ever experienced at work; [b]Symptoms (ocular-nasal/chest) ever experienced at work that improves when away from work
Each OR represents a separate adjusted for age, gender, atopy and smoking

Table 7.6a: Association between current inhalable dust exposure in relation to lung function indices and airway obstruction among wood processing workers in Mozambique based on multivariate regression models

	Prevalence n (%)	Baseline FEV_1/FVC	Baseline FEV_1/FVC <0.7	PBD FEV_1/FVC	PBD FEV_1/FVC <0.7
Prevalence: n (%)		-	83 (19)	-	58 (14)
Mean current dust concentration (mg/m^3)		1.00 (0.99 – 1.01)	1.08 (0.91 – 1.29)	1.00 (0.99 – 1.10)	1.00 (0.81 – 1.24)
Current exposure categories based on current job titles					
Low (maintenance, upholsterer)	24 (8)	1	1	1	1
Medium (machine operator, painter-varnisher, assembler)	226 (73)	1.03 (0.97 – 1.08)	0.95 (0.29 – 3.16)	1.04 (0.98 – 1.11)	0.59 (0.17 – 1.99)
High (planer, sander, sawyer, carver)	58 (19)	1.02 (0.96 – 1.09)	1.54 (0.39 – 6.04)	1.02 (0.95 – 1.09)	0.86 (0.20 – 3.69)
Current exposure categories based on dust levels					
Low (<4.68 mg/m^3)	24 (8)	1	1	1	1
Medium (4.68-4.71 mg/m^3)	142 (46)	1.02 (0.96 – 1.08)	0.93(0.27 – 23.18)	1.04 (0.97 – 1.10)	0.63 (0.18 – 2.21)
High (>4.71 mg/m^3)	142 (46)	1.03 (0.97 – 1.09)	1.16 (0.34 – 3.99)	1.04 (0.97 – 1.11)	0.62 (0.17 – 2.22)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Fixed airway obstruction: PBD FEV_1 /FVC < 70%
Each OR represents a separate adjusted for age, gender, atopy and smoking.

Table 7.6b: Association between cumulative inhalable dust exposure in relation to lung function indices and airway obstruction among wood processing workers in Mozambique based on multivariate regression models

	Prevalence n (%)	Baseline FEV_1/FVC	Baseline FEV_1/FVC <0.7	PBD FEV_1/FVC	PBD FEV_1/FVC <0.7
Prevalence: n (%)		-	83 (19)	-	58 (14)
Crude overall cumulative exposure in the factory (mg/m^3-yr)		1.00 (0.99 – 1.00)	0.99 (0.99 – 1.00)	1.00 (0.99 – 1.00)	0.99 (0.98 – 1.00)
Overall cumulative exposure over all the jobs (mg/m^3-yr)		1.00 (0.99 – 1.00)	0.99 (0.99 – 1.00)	1.00 (0.99 – 1.00)	0.99 (0.98 – 1.00)
Cumulative exposure based on current job according to quartiles					
Quartile 1 <=10.09 (mg/m^3-yr)	82 (27)	1	1	1	1
Quartile 2 >10.09 and <=31.335 (mg/m^3-yr)	72 (23)	1.02 (0.98 – 1.07)	1.05 (0.40 – 2.79)	0.99 (0.94 – 1.03)	1.25 (0.40 – 3.91)
Quartile 3 >31.335 and <=61.035 (mg/m^3-yr)	77 (25)	1.00 (0.96 – 1.05)	1.37 (0.54 – 3.44)	0.98 (0.93 – 1.03)	1.02 (0.32 – 3.19)
Quartile 4 >61.035 (mg/m^3-yr)	77 (25)	1.02 (0.97 – 1.07)	0.92 (0.34 – 2.50)	0.98 (0.93 – 1.03)	0.78 (0.24 – 2.52)
Cumulative exposure overall all jobs according to quartiles					
Quartile 1 <= 9.405 (mg/m^3-yr)	84 (25)	1	1	1	1
Quartile 2 > 9.405 and < =27.94 (mg/m^3-yr)	84 (25)	1.02 (0.98 – 1.06)	0.78 (0.32 – 1.96)	0.97 (0.93 – 1.01)	2.05 (0.70 – 6.02)
Quartile 3 > 27.94 and <= 60.54 (mg/m^3-yr)	86 (26)	1.02 (0.98 – 1.06)	0.77 (0.32 – 1.85)	0.99 (0.95 – 1.03)	0.84 (0.26 – 2.72)
Quartile 4 > 60.54 (mg/m^3-yr)	82 (24)	1.03 (0.98 – 1.07)	0.67 (0.27 – 1.71)		1.05 (0.34 – 3.28)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Fixed airway obstruction: PBD FEV_1 /FVC < 70%
Each OR represents a separate adjusted for age, gender, atopy and smoking

Table 7.7a: Association between current inhalable dust exposures in relation to airway reversibility among wood processing workers in Mozambique based on multivariate regression models

	Prevalence n (%)	FEV_1 (ln) PBD increase (%)	FEV_1 (ln) PBD increase (% pred)	PBD ΔFEV1% ≥ 9% of the predicted FEV_1	PBD ≥12% and ≥ 200 ml FEV_1 increase
Prevalence: n (%)		-	-	24 (6)	14 (3)
Mean current dust concentration (mg/m^3)		1.01 (0.94 -1.07)	1.02 (0.95 – 1.08)	0.97 (0.71 – 1.33)	1.07 (0.80 – 1.72)
Current exposure categories based on current job titles					
Low (maintenance, upholsterer)	24 (8)	1	1	1	1
Medium (machine operator, painter-varnisher, assembler)	226 (73)	**1.91 (1.21 – 3.03)****	**1.95 (1.26 – 3.00)****	NC	NC
High (planer, sander, sawyer, carver)	58 (19)	1.67 (0.97 – 2.86)	**1.72 (1.04 – 2.83)***	NC	NC
Current exposure categories based on dust levels					
Low (<4.68 mg/m^3)	24 (8)	1	1	1	1
Medium (4.68-4.71 mg/m^3)	142 (46)	**1.99 (1.25 – 3.22)****	**2.03 (1.31 – 3.16)****	NC	NC
High (>4.71 mg/m^3)	142 (46)	**1.73 (1.07 – 2.80)***	**1.77 (1.14 – 2.77)***	NC	NC

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Airway reversibility: ≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD ΔFEV_1% ≥9% of the predicted FEV_1
Each OR represents a separate adjusted for age, gender, atopy and smoking
NC: not calculable

Table 7.7b: Association between cumulative inhalable dust exposure in relation to airway reversibility among wood processing workers in Mozambique based on multivariate regression models

	Prevalence n (%)	FEV_1 (ln) PBD increase (%)	FEV_1 (ln) PBD increase (% pred)	PBD ΔFEV1% ≥ 9% of the predicted FEV_1	PBD ≥ 12% and ≥ 200 ml FEV_1 increase
Prevalence: n (%)		-	-	24 (6)	14 (3)
Mean cumulative exposure based on current job in the factory (mg/m^3-yr)		0.99 (0.99 – 1.00)	1.00 (1.00 – 1.00)	0.99 (0.98 – 1.01)	1.00 (0.99 – 1.02)
Mean cumulative exposure based on all jobs in the factory (mg/m^3-yr)		0.99 (0.99 – 1.00)	1.00 (0.99 – 1.00)	0.99 (0.98 – 1.01)	1.01 (0.99 – 1.02)
Cumulative exposure based on current job					
Quartile 1 <=10.09 (mg/m^3-yr)	82 (27)	1	1	1	1
Quartile 2 >10.09 and <=31.335 (mg/m^3-yr)	72 (23)	0.76 (0.54 – 1.08)	0.78 (0.57 – 1.08)	1.26 (0.25 – 6.29)	NC
Quartile 3 >31.335 and <=61.035 (mg/m^3-yr)	77 (25)	0.85 (0.61 – 1.21)	0.86 (0.62 – 1.19)	0.92 (0.17 – 4.83)	0.46 (0.05 – 4.10)
Quartile 4 >61.035 (mg/m^3-yr)	77 (25)	0.89 (0.61 – 1.30)	0.86 (0.61 – 1.22)	0.47 (0.07 – 3.03)	0.69 (0.10 – 4.49)
Cumulative exposure overall all jobs					
Quartile 1 <= 9.405 (mg/m^3-yr)	84 (25)	1	1	1	1
Quartile 2 > 9.405 and < =27.94 (mg/m^3-yr)	84 (25)	1.00 (0.73 – 1.39)	1.03 (0.76 (1.39)	0.83 (0.15 – 4.53)	NC
Quartile 3 > 27.94 and <= 60.54 (mg/m^3-yr)	86 (26)	0.99 (0.72 – 1.38)	1.00 (0.74 – 1.35)	1.30 (0.28 – 6.15)	0.51 (0.06 – 4.26)
Quartile 4 > 60.54 (mg/m^3-yr)	82 (24)	1.04 (0.73 – 1.49)	1.01 (0.73 – 1.40)	0.54 (0.09 – 3.39)	0.75 (0.10 – 5.27)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
Airway reversibility: ≥12% and ≥200 ml FEV_1 increase post-bronchodilator; PBD ΔFEV_1% ≥9% of the predicted FEV_1
Each OR represents a separate adjusted for age, gender, atopy and smoking
NC: not calculable

7.3.8 Association between current as well as cumulative dust exposure and exhaled nitric oxide (FeNO) based on multivariate regression models

In the multivariate models, increasing FeNO was associated with cumulative dust exposure based on current job, quartile 2 (OR= 1.32, 95% CI: 1.07 – 1.63) as well across all jobs in the factory (OR= 1.22, 95% CI: 1.00 – 1.48) (Table 7.8a-b). When a higher cut-off for FeNO >50ppb, indicative of allergic airway inflammation, much higher odds ratios were observed, but did not reach statistical significance.

Table 7.8a: Association between current inhalable dust exposure and exhaled nitric oxide (FeNO) among wood processing workers in Mozambique based on multivariate regression models

	Prevalence n (%)	FeNO (ln), ppb	FeNO ≥ 25 ppb	FeNO ≥ 50 ppb	FeNO 25-50 ppb vs FeNO <25 ppb	FeNO>50 ppb vs FeNO <25 ppb
Prevalence: n (%)		-	126 (28)	22 (5)	104 (23)	22 (5)
Mean current dust concentration (mg/m^3)		1.01 (0.97 – 1.05)	0.95 (0.82 – 1.09)	1.14 (0.87 – 1.46)	0.91 (0.78 – 1.06)	1.11 (0.86 – 1.43)
Current exposure categories based on current job titles						
Low (maintenance, upholsterer)	24 (8)	1	1	1	1	1
Medium (machine operator, painter-varnisher, assembler)	226 (73)	1.14 (0.85 – 1.52)	1.23 (0.44 – 3.41)	1.03 (0.12 – 8.81)	1.24 (0.42 – 3.66)	1.11 (0.13 – 9.65)
High (planer, sander, sawyer, carver)	58 (19)	1.15 (0.82 – 1.62)	0.96 (0.30 – 3.10)	1.30 (0.13 – 13.32)	0.86 (0.24 – 2.06)	1.25 (0.12 – 13.18)
Current exposure categories based on dust levels						
Low (<4.68 mg/m^3)	24 (8)	1	1	1	1	1
Medium (4.68-4.71 mg/m^3)	142 (46)	1.19 (0.88 – 1.60)	1.44 (0.51 – 4.08)	1.40 (0.16 – 12.33)	1.39 (0.46 – 4.21)	1.57 (0.17 – 14.09)
High (>4.71 mg/m^3)	142 (46)	1.09 (0.81 – 1.48)	0.93 (0.33 – 2.69)	0.81 (0.09 – 7.34)	0.96 (0.31 – 2.94)	079 (0.08 – 7.44)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
FeNO (ln): Fractional exhaled nitric oxide (natural log)
Each OR represents a separate adjusted for age, gender, atopy and smoking

Table 7.8b: Association between cumulative inhalable dust exposure and exhaled nitric oxide (FeNO) among wood processing workers in Mozambiquebased on multivariate regression models

	Prevalence n (%)	FeNO (ln), ppb	FeNO ≥ 25 ppb	FeNO ≥ 50 ppb	FeNO 25-50 ppb vs FeNO <25 ppb	FeNO>50 ppb vs FeNO <25 ppb
Prevalence: n (%)		-	126 (28)	22 (5)	104 (23)	22 (5)
Mean cumulative exposure based on current job in the factory (mg/m^3-yr)		1.00 (0.99 – 1.00)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.02)
Mean cumulative exposure based on all jobs in the factory(mg/m^3-yr)		1.00 (0.99 – 1.00)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.02)	1.00 (0.99 – 1.01)	1.00 (0.99 – 1.02)
Cumulative exposure based on current job						
Quartile 1 <=10.09 (mg/m^3-yr)	82 (27)	1	1	1	1	1
Quartile 2 >10.09 and <=31.335 (mg/m^3-yr)	72 (23)	**1.32 (1.07 – 1.63)****	1.53 (0.73 – 2.20)	5.08 (0.98 – 26.41)	1.22 (0.56 – 2.68)	4.92 (0.93 – 26.09)
Quartile 3 >31.335 and <=61.035 (mg/m^3-yr)	77 (25)	1.11 (0.90 – 1.36)	1.02 (0.47 – 2.20)	3.43 (0.59 – 19.97)	0.94 (0.37 – 1.90)	3.11 (0.52 – 18.42)
Quartile 4 >61.035 (mg/m^3 -yr)	77 (25)	1.20 (0.95 – 1.51)	1.37 (0.61 – 3.06)	2.52 (0.36 – 17.42)	1.25 (0.54 – 2.89)	2.55 (0.36 -17.94)
Cumulative exposure overall all jobs						
Quartile 1 <=9.405 (mg/m^3-yr)	84 (25)	1	1	1	1	1
Quartile 2 >9.405 and < =27.94 (mg/m^3-yr)	84 (25)	**1.22 (1.00 – 1.48)***	1.23 (0.61– 2.50)	2.41 (0.56 – 10.38)	1.07 (0.50 – 2.29)	2.46 (0.56 – 10.78)
Quartile 3 >27.94 and <=60.54 (mg/m^3-yr)	86 (26)	1.05 (0.86 – 1.28)	0.97 (0.47 – 1.99)	2.51 (0.57 – 11.09)	0.80 (0.37 – 1.74)	2.36 (0.53 – 10.60)
Quartile 4 >60.54 (mg/m^3-yr)	82 (24)	1.17 (0.94 – 1.45)	1.30 (0.61 – 2.77)	1.15 (0.19 – 7.01)	1.29 (0.59 – 1.03)	1.25 (0.20 – 7.78)

Data are presented as OR (95% CI), unless otherwise indicated. OR: odds ratio; CI: confidence interval; *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001
FeNO (ln): Fractional exhaled nitric oxide (natural log)
Each OR represents a separate adjusted for age, gender, atopy and smoking

7.4 DISCUSSION

This study of workers in the Mozambiquan wood processing industry, was successful in exploring the nature of exposure-response relationships between inhalable particulate wood dust exposures generated during work activities and work-related asthma, by using multiple exposure metrics (current and cumulative exposure) and clinical indices of obstructive lung disease (work-related respiratory symptoms, airway obstruction, bronchial reversibility and exhaled nitric oxide), thereby contributing towards the body of evidence confirming this association and promoting a better understanding of the phenotypic manifestations and the possible underlying mechanisms.

In this study work-related ocular-nasal symptoms were associated with current inhalable dust exposures, with at least a threefold increase in riskin a dose-dependent manner. These results are consistent with the Tanzanian study reported by Rongo at al. (7), in which ocular-nasal symptoms were strongly associated with exposure to wood dust (OR= 3.2, 95% CI: 1.7– 6.1). Interestingly, work-related ocular-nasal symptoms were negatively associated with cumulative exposure. This may be related to a healthy worker effect, in that symptomatic workers are likely to change jobs by moving from high to less dusty areas due to their symptoms.

With regard to work-related asthma symptoms, these were positively associated with increasing levels of cumulative dust exposure. A consistent dose response trend was seen across all quartiles in the unadjusted (Q2, OR= 1.00, 95% CI: 0.39 – 2.54; Q3, OR= 1.20, 95% CI: 0.49 – 2.95; Q4, OR= 1.94, 95 CI: 0.83 – 4.52) and adjusted models, although it was not statistically significant. Schlünssen et al. also reported a dose-response relationship between wood dust exposure and asthma symptoms in Danish wood workers, and a positive interaction was observed for asthma between female gender and dust exposure(2). Similar dose-response relationships have been observed in rubber wood (*Hevea brasiliensis*) factories in Thailand by Sripaiboonkij et al.(23), demonstrating that the risk of wheezing increased with dust exposure (OR 2.51 and 2.97 in the low and high exposure groups, respectively).

In this current study, no consistent dose-response associations were observed between the exposure metrics and indices of airway obstruction based on the post-bronchodilator FEV_1/FVC ratio (24). However, a negative trend was observed between cumulative dust exposure and the post- bronchodilator ratio in a dose dependent manner, but these associations were not statistically significant in the multivariate models suggesting lack of power playing a possible role. There are various other studies that have demonstrated dose-response relationship between the level of exposure and decline in lung function indices among wood workers in different settings in cross-sectional and longitudinal studies (3, 4, 11, 12, 25, 26,27). Mandryk et al. (28) also reported that green mill workers showed significant inverse relationships between personal exposures [dust, (1 → 3)-β-D-glucan, fungi and Gram (-)ve bacteria] and predicted lung function as well as positive correlations between personal dust exposures and cross-shift decline in lung function. Dry mill workers, on the hand demonstrated positive associations only between duration of exposure to wood dust and cross- shift decrements in VC ($r = 0.40$, $P = 0.02$) and $FEF_{25\text{-}75\%}$ ($r = 0.33$, $p = 0.05$). Douwes et al. (14) also found that FVC, FEV_1 and peak expiratory flow were significantly lower in workers exposed to high levels of green dust (-350 mL, -260 mL and -860 mL.s-1, respectively) versus dry dust (-230 mL, -190 mL and -850 mL.s-1, respectively). It was not possible to conduct this analysis in the current study since most workers worked with green and dry wood.

In this current study, increasing levels of bronchial reversibility was positively associated with current inhalable dust particulate exposures based using more than one exposure metric (job titles, actual dust levels), suggesting an acute irritative response, although an allergic response cannot be entirely excluded. However, this trend was not observed using cumulative dust exposure metrics in the multivariate models of the current study. This contrasts with the findings reported by Bohadana et al.(10) among furniture workers processing mainly beech (Fagus sp) and oak (Quercus sp) wood, in which subjects with a positive methacholine bronchial challenge test and having a steep methacholine dose-response slope were significantly associated with increasing cumulative dust exposures. Schlünssen et al. (4) also found that symptomatic bronchial responsiveness (BHR) was related to dust in a dose dependent manner and modified by atopic status.

Using a biomarker of airway inflammation, FeNO, was positively associated with cumulative dust exposure using both exposure metrics in the unadjusted models. In the adjusted models, the positive association persisted, but was not statistically significant for all quartiles, most likely due to a lack of power. Using a higher cut-off for FeNO>50ppb, which is highly suggestive of allergic airway inflammation, the odds ratios increased two to three-fold across all quartiles. These findings suggest possible underlying chronic allergic airway inflammation in workers with long-term wood dust exposures. To our knowledge, this is the first study to demonstrate such a relationship in an epidemiological study of wood workers. This is consistent with the study findings of workers exposed to plant derived dusts by van der Walt et al. (29) in which a positive trend was also observed between airborne spice dust particulate and serial changes in FeNO.

Overall, the findings of this current study suggest a predominant acute irritant dose-response relationship in ocular-nasal symptoms and bronchial reversibility patterns given the relatively high levels of dust produced in processing (GM: 3.29 mg/m^3, range: 0.33 – 119.36 mg/m^3)and possible underlying chronic allergic airway inflammation with chronic exposures. This latter deduction is also based on the inability of the laboratory to detect specific IgE antibodies to commonly used wood species in Mozambique (Panga-panga, Mahogany bean, African mahogany, African teak, Ironwood and Pine) in the sera of five index patients with work-related asthma (personal communication, Sabine Kespohl, BGFA). Studies show that although specific sensitization to wood dust exists, it is probably of minor importance for most wood species as the underlying pathophysiological mechanism for occupational asthma in exposed workers.

This study of wood processing workers in Mozambique was able to explore important dose-response associations using data obtained from exposure characterisation environmental sampling studies. In this way exposure metrics for current exposure (based on job title and actual dust levels) as well as cumulative exposures were used to assess dose-response relationships for acute and chronic exposures respectively. In addition to symptom data and lung function indices, FeNO was also used as an objective marker of allergic airway inflammation in the absence of specific IgE tests to wood dust species being available.

However, there were also important limitations that need to be highlighted for future studies. Being a cross-sectional study, it also suffered from the healthy worker effect in that we were unable to demonstrate significant associations between cumulative wood dust exposure and bronchial hyper-responsiveness nor between current wood dust exposures and FeNO. It is probable that a proportion of workers (2%) left their jobs or moved to less dusty operations in the factory. Furthermore, the nature of the study design was unable to establish the temporality between exposure and the outcomes of interest. A cohort study design would have strengthened the ability to demonstrate such associations with greater degree of certainty. Due to the limited number of environmental sample data, it is possible that the variability of exposures was not optimal, contributing to the lack of power in exploring associations more fully. Since, only particulate exposures were explored, future studies should also look at relationships with endotoxins and glucans as well as improved testing for allergens and terpenes to enhance the characterisation of these relationships. Furthermore, more sensitive measures for bronchial hyperresponsivess (methacholine/histamine challenge) should also be included in assessing the presence of underlying asthma. Finally, future research needs to characterise asthma-COPD overlap syndrome in relation to wood dust exposures so as to better understand this entity.

7.5 CONCLUSION

Overall, the findings of this current study suggest a predominant acute irritant dose-response relationship related to work-related ocular-nasal and asthma symptoms as well as bronchial reversibility patterns given the relatively high levels of dust produced in wood processing and possible underlying chronic airway inflammation due to chronic wood dust exposures. The findings of this study has demonstrated positive exposure-response relationships between inhalable particulate wood dust exposures generated during work activities and work-related ocular-nasal symptoms and asthma of a more acute irritant nature and associated with possible chronic airway inflammation due to toxins (endotoxins and mycotoxins) and undetected allergens associated with the wood dust.

7.6 REFERENCES

1. Pérez-Ríos M, Ruano-Ravina A, Etminan M, Takkouche B. A meta-analysis on wood dust exposure and risk of asthma. Allergy. 2010;65(4):467–73.
2. Schlünssen V, Schaumburg I, Taudorf E, Mikkelsen AB, Sigsgaard T. Respiratory symptoms and lung function among Danish woodworkers. J Occup Environ Med. 2002;44(1):82–98.
3. Jacobsen G, Schlünssen V, Schaumburg I, Sigsgaard T. Increased incidence of respiratory symptoms among female woodworkers exposed to dry wood. Eur Respir J. 2009;33(6):1268–76.
4. Schlünssen V, Schaumburg I, Heederik D, Taudorf E, Sigsgaard T. Indices of asthma among atopic and non-atopic woodworkers. Occup Environ Med. 2004;61(6):504–11.
5. Lytras T, Kogevinas M, Kromhout H, Carsin A-E, Antó JM, Bentouhami H, et al. Occupational exposures and 20-year incidence of COPD: the European Community Respiratory Health Survey. Thorax. 2018;0:1–8.
6. Heikkilä P, Martikainen R, Kurppa K, Husgafvel-Pursiainen K, Karjalainen A. Asthma incidence in wood-processing industries in Finland in a registerbased population study. Scand J Work Environ Heal Suppl. 2008;34(1):66–72.
7. Rongo LMB, Besselink A, Msamanga GI, Dolmans WM V, Demers PA, Heederik D.

Respiratory Symptoms and Dust Exposure Among Male Workers in Small-Scale Wood Industries in Tanzania. J Occup Environ Med. 2002;44(12):1153–60.

8. Wiggans RE, Sumner J, Robinson E, Barber CM. Respiratory symptoms, lung function and sensitisation across different exposure groups of British woodworkers. Thorax. 2017;72(3):A1-278.
9. Chaiear N, Ngoencharee J, Saejiw N. Respiratory Symptoms and Pulmonary Function among Workers in a Rubber Wood Sawmill Factory in Thailand. Am J Public Heal Res. 2018;6(2):65–71.
10. Bohadana AB, Massin N, Wild P, Toamain JP, Engel S, Goutet P. Symptoms, airway responsiveness, and exposure to dust in beech and oak wood workers. Occup Environ Med. 2000;57(4):268–73.
11. Noertjojo HK, Dimich-Ward H, Peelen S, Dittrik M, Kennedy SM, Chan-Yeung M. Western red cedar dust exposure and lung function: A dose-response relationship. Pneumologie. 1997;51(12):141–6.
12. Bolund ACS, Miller MR, Jacobsen GH, Sigsgaard T, Schlünssen V. New-onset COPD and Decline in Lung Function Among Wood Dust-Exposed Workers : Re-analysis of a 6-year Follow-up Study. Ann Work Expo Heal. 2018;20(20):1–13.
13. Löfstedt H, Hagström K, Bryngelsson IL, Holmström M, Rask-Andersen A. Respiratory symptoms and lung function in relation to wood dust and monoterpene exposure in the wood pellet industry. Ups J Med Sci. 2017;122(2):78–84.
14. Douwes J, Mclean D, Slater T, Travier N, Cheng S, Pearce N. Pine dust, atopy and lung function: a cross- sectional study in sawmill workers. Eur Respir J. 2006;28:791–8.
15. Schlünssen V, Kespohl S, Jacobsen G, Raulf-Heimsoth M, Schaumburg I, Sigsgaard T. Immunoglobulin E-mediated sensitization to pine and beech dust in relation to wood dust exposure levels and respiratory symptoms in the furniture industry. Scand J Work Environ Heal. 2011;37(2):159–67.
16. Schluenssen V, Sigsgaard T, Raulf-Heimsoth M, Kespohl S. Workplace exposure to wood dust and the prevalence of wood-specific sensitization. Allergologie. 2012;35(8):402–12.
17. Tuomisto LE, Ilmarinen P, Lehtimäki L, Tommola M, Kankaanranta H. Immediate bronchodilator response in FEV 1 as a diagnostic criterion for adult asthma. Eur Respir J. 2019;53(2):1–7.
18. Coman I, Lemie C. Fractional exhaled nitric oxide (FeNO) in the screening and diagnosis work-up of occupational asthma. Curr Treat Options Allergy. 2017;4:145–59.

19. Miller MR, Crapo R, Hankinson J, Brusasco V, Burgos F, Casaburi R, et al. General considerations for lung function testing. Eur Respir J. 2005;26(1):153–61.
20. ATS and ERS. ATS/ERS recommendations for standardized procedures for the online and offline measurement of exhaled lower respiratory nitric oxide and nasal nitric oxide, 2005. Am J Respir Crit Care Med. 2005;171(8):912–30.
21. Bjermer L, Alving K, Diamant Z, Magnussen H, Pavord I, Piacentini G, et al. Current evidence and future research needs for FeNO measurement in respiratory diseases. Respir Med. 2014;108(6):830–41.
22. Dweik RA, Boggs PB, Erzurum SC, Irvin CG, Leigh MW, Lundberg JO, et al. An Official ATS Clinical Practice Guideline: Interpretation of Exhaled Nitric Oxide Levels (FE NO) for Clinical Applications. Am J Respir Crit Care Med. 2011;184:602–15.
23. Sripaiboonkij P, Phanprasit W, Jaakkola MS. Respiratory and skin effects of exposure to wood dust from the rubber tree Hevea brasiliensis. Occup Environ Med. 2009;66(7):442–7.
24. Vogelmeier CF, Criner GJ, Martinez FJ, Anzueto A, Barnes PJ, Bourbeau J, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease 2017 report. American Journal of Respiratory and Critical Care Medicine. 2017;195(5):1-39.
25. Jacobsen G, Schlünssen V, Schaumburg I, Taudorf E, Sigsgaard T. Longitudinal lung function decline and wood dust exposure in the furniture industry. Eur Respir J. 2008;31(2):334–42.
26. Mandryk J, Alwis KU, Hocking AD. Work-related symptoms and dose-response relationships for personal exposures and pulmonary function among woodworkers. Am J Ind Med. 1999;35(5):481–90.
27. Teschke K, Spierings J, Marion SA, Demers PA, Davies HW, Kennedy SM. Reducing attenuation in exposure-response relationships by exposure modeling and grouping: The relationship between wood dust exposure and lung function. Am J Ind Med. 2004;46(6):663–7.
28. Mandryk J, Alwis KU, Hocking AD. Effects of Personal Exposures on Pulmonary Function and Work-related Symptoms Among Sawmill Workers. Ann Occup Hyg. 2000;44(4):281–9.
29. van der Walt A, Singh T, Baatjies R, Lopata AL, Jeebhay MF. Work-related allergic respiratory disease and asthma in spice mill workers is associated with inhalant chili pepper and garlic exposures. Occup Environ Med. 2013;0:1–7.

CHAPTER 8

Summary of study findings, recommendations and conclusion

8.1. SUMMARY OF STUDY FINDINGS

This study investigating the risk of work-related asthma (WRA) and rhinitis associated with wood dust exposures among workers in the Mozambiquan wood processing industry has demonstrated that inhalable exposures to all three exposure parameters (wood dust particulate, glucan and endotoxin) exceeded international standards. The prevalence of asthma was 7% (atopic asthma 4%, non-atopic asthma 4% and work-related asthma 2%), which is on the upper end of the range reported for woodworkers in other African countries (3-7%), but on the lower end of the range reported for countries beyond the continent (6-18%). In addition to using the standardised ECRHS questionnaire for asthma, the study also used objective markers for bronchial reversibility and airway inflammation (FeNO) to better characterise asthma phenotypes present.

The novel findings of this study included the demonstration of certain wood species such as African sandalwood (*Spirostachys Africana Sonder*) and mahogany bean (*Afzelia quanzensis Welw*) and factory building features (closed and semi-closed buildings) as being associated with higher inhalable dust levels, while cleaning activities using damp cleaning methods were associated with lower dust levels. Furthermore, working with Missanda (*Erythrophleum suaveolens Brenan*), Mahogany bean (*Afzelia quanzensis Welw.*) and Panga-panga (*Millettia Stuhlmannii Taub*) wood species was associated with work-related ocular-nasal symptoms whereas working with Mutondo (*Cordyla Africana*) wood species was associated with both work-related ocular-nasal and asthma symptoms. Finally, positive exposure-response relationships were demonstrated between inhalable wood dust particulate exposures and work-related ocular-nasal and asthma endpoints, suggestive of an acute irritant nature with underlying chronic airway inflammation. This is consistent with most previous studies, which demonstrated that although specific sensitization to wood dust exists for certain wood species, it is probably of limited importance for most wood species.

8.1.1. CHARACTERISATION OF WOOD DUST PARTICULATE, ENDOTOXINS AND GLUCANS EXPOSURES AND THEIR DETERMINANTS

Various exposure assessment studies have reported that workers in the wood processing industry are exposed to variable concentrations of hazardous agents (microorganisms, endotoxins, glucans and terpenes) associated with wood dust (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11).

However, there are few studies that have conducted a comprehensive assessment of dust particulate and associated contaminant exposures and the factors that contribute towards excessive exposures, especially in African settings. Furthermore, no previous studies have assessed the role of exotic wood species used in the Mozambiquan wood processing industry and factors such as building design (open, semi-open and closed), building size, use of ventilation and cutting tools, and work practices, influence wood dust exposures to increase the risk of work-related asthma.

This study has done comprehensive exposure assessment, which included measurement of inhalable wood dust particulate, glucans and endotoxins and obtained information on various parameters that may predict wood dust particulate or contaminant exposures. These included among other the factory location, job titles and exposure groups, wood species processed, physical state of woods, building design (open, semi-closed or closed), building size, number of workers employed, presence of engineering controls, frequency of sharpening cutting tools, wood dust cleaning methods, frequency of cleaning surfaces and floors, laundering working clothes, waste disposal methods, use of PPE and dust control training **(Chapter 4)**.Using various modelling techniques, this study demonstrated that aside from working in a similar exposure group (due to the close proximity of related jobs being physically located in the same area), working with certain wood species (African sandalwood and mahogany bean) and certain building design characteristics (closed and semi-closed buildings) were associated with higher inhalable dust particulate, endotoxin and β-glucan exposures. Whereas, working with other wood species (Panga-panga and African teak wood) and employing cleaning methods that used damp cloths were associated with lower dust exposures.

The workers in the Mozambique wood processing industry were exposed to several types of woods, the most common being African teak (*Pterocarpus angolensis DC*) and Mahogany bean (*Afzelia quanzensis Welw*.) (75%), followed by Panga-panga (*Millettia Stuhlmannii Taub*) (55%) and Pine (*Pinus sp*) (42%), which were different from wood species used in other African studies (1, 11, 12, 13). The study also found that the mean (GM) dust particulate exposures were high (3.29 mg/m^3) compared to international exposure standards (ACGIH: 0.5 mg/m^3 for Western red ceder, 1 mg/m^3 for all other species, European Union: 1 – 1.5 mg/m^3 , Sweden and Norway: 2 mg/m^3, The Netherlands: 0.2 mg/m^3)(14, 15, 17). For endotoxins, mean exposures were 98 endotoxin units (EU)/m^3, which is mildly elevated according to international exposure standards (Dutch Expert Committee on Occupational Safety and Committee of the Health

Council of the Netherlands: 90 EU/m^3) (17). For (1-3)-β-D-Glucans, the mean exposures were 123 ng/m^3. Unlike for dust particulate and endotoxins, no exposure standards for (1→3)-β-D-glucans. However, it is much higher compared to therange of 0.1–5.2 ng/m^3 referred to by Rylander(18) in determining the increased frequency of adverse health effect occurrences in exposed populations.

This study has also shown that belonging to certain exposure groups (sawing, painting, carpentry and machinery) and working with certain wood species (African sandalwood and Mahogany bean wood) were associated with elevated dust particulate exposures. Whilst, working with other wood species (African teak and Panga-panga) as well as using damp cloths for cleaning were associated with lower particulate levels. The significant determinants of elevated endotoxin exposures included working with African sandalwood, working in closed buildings and work that involved sawing of wood. On the other hand, working with Panga-panga wood species, using dry wood, performing joinery work and painting, as well as cleaning using damp cloths were associated with lower endotoxin levels. Semi-closed buildings were the main determinants of elevated inhalable (1-3)-β-D-glucan levels. Whilst, using damp cloths for cleaning were associated with decreased levels.

These findings are novel for the Mozambiquan wood processing industry and also have implications for wood workers on the African continent and beyond where similar production processes and tree species are used.

8.1.2. WORK-RELATED RESPIRATORY SYMPTOMS, AIRWAY REVERSIBILITY AND INFLAMMATION

This is the first study to characterise various asthma phenotypes in wood processing workers using a repertoire of asthma indices that included symptoms, bronchial reversibility and exhaled nitric oxide levels. Using standardized ECRHS asthma questions, the prevalence of current asthma was 7%, with equal proportions of atopic and non-atopic asthma (4%) being present, while 2% of wood processing workers had work-related asthma. Given that asthma symptom scores (ASS) can be useful in identifying asthma cases in epidemiological studies instead of dichotomous definitions of asthma (19, 20, 21), there were 10% of workers with an ASS ≥ 2, being the more symptomatic. Using lung function indices, significant bronchial reversibility was present in 3-6% of workers, while 5% had high FeNO levels (>50 ppb) suggestive of underlying airway inflammation (22, 23) (**Chapter 5**). Furthermore, FeNO is also an important sub-clinical marker for identification of individuals with asthma. All these estimates obtained using difference indices are relatively consistent with each other. To the best of our knowledge, this is the first Mozambiquan study to report on the prevalence of adult asthma in general. Overall, the figures for asthma are on the upper end of the range reported for woodworkers in other African countries (3-7%), but on the lower end of the range reported for countries beyond the continent (6-18%). This was also the first study that has used two approaches to assess bronchial reversibility (PBD) among woodworkers: as ≥12% and ≥200 ml FEV_1 increase post-bronchodilator (24) and as ≥9% FEV_1 increase post-bronchodilator as a proportion of FEV1 % predicted (25), adding to the robustness of the measures to ascertain the presence of asthma.

In the current study, 34% of subjects reported presence of general ocular-nasal symptoms. As to be expected the prevalence of work-related lower respiratory symptoms were much lower than work-related ocular-nasal symptoms. There were 14% of workers with a history of experiencing work-related chest symptoms, while at least 8% reported their chest symptoms improving when away from work, the latter being a better marker of work-relatedness. Wood dust exposure was reported to be a main cause of both chest symptoms (12%) and ocular-nasal symptoms (36%), more so the latter suggesting probably a major irritative component attributable to the high wood dust particulate exposures. While the overall prevalence of airflow obstruction in this study was 19%, one third (6%) among these workers had bronchial reversibility suggestive of asthma, while the remaining two thirds had evidence of fixed airway obstruction suggestive of chronic obstructive pulmonary disease (COPD). The latter is a sizeable disease burden that merits further investigation.

8.1.3 HOST AND ENVIRONMENTAL RISK FACTORS ASSOCIATED WITH ASTHMA-RELATED OUTCOMES

Various studies have partially examined the role of individual host and environmental risk factors in rhinitis and asthma among wood processing workers (26, 27, 28, 29, 30, 31).

This study, doing a comprehensive assessment of individual host and environmental risk factors for work-related rhinitis and asthma among Mozambiquan wood processing workers, identified some important risk factors. One of the novel components of this current study is the identification of particular indigenous exotic wood species such as Mutondo (*Cordyla Africana*), Missanda (*Erythrophleum suaveolens Brenan*), Panga-panga (*Millettia Stuhlmannii Taub*) and Mahogany bean (*Afzelia quanzensis Welw*.) that was strongly associated with work-related ocular nasal symptoms, while with the Mutondo (*Cordyla Africana*) wood species was associated with both work-related ocular-nasal and asthma symptoms (**Chapter 6**).

In this study, higher general asthma symptom scores were found in workers reporting a family history of allergy, adult-onset asthma diagnosis, and being female. With regard to work-related asthma symptoms (WRAS) the study demonstrated that this was more likely in current smokers and those with hay fever (rhinitis). The determinants of exhaled nitric oxide (FeNO) in wood workers have been studied for the first time. Workers that were male, atopic, or who had asthma had higher levels of FeNO, as has been frequently observed in other occupational studies. These factors were considered as potential confounders when exposure response relationships for asthma were investigated further (32).

Among the self-reported environmental predictors, belonging to the medium (machine operators, painter-varnishers and assemblers), and high (planers, sanders, sawyers and carvers) exposure group as associated with work-related ocular nasal symptoms (WRONS). These exposure groups were also well correlated with belonging to the medium (mean: 1.80 - 4.71 mg/m^3) and high (mean: 6.99 - 10.84 mg/m^3) exposure category.

When considering more objective indices of asthma in relation to occupational risk factors, employment duration was significantly associated with both reversible airway obstruction and increasing levels of FeNO, suggesting further evidence of an exposure response relationship in wood workers. With regard to reversible airway obstruction, the findings of this study are also consistent with other studies among wood processing workers in Africa and beyond (12, 29, 33).

The associations between cleaning activities and the risk of adverse upper and lower respiratory health outcomes were consistent. Cleaning equipment was significantly associated with a relatively lower asthma symptom score as was general cleaning activities and bronchial reversibility in the final multivariate models. The protective respiratory health effect of cleaning activities is consistent with the findings of the exposure assessment part of study (**Chapter 4**), in which tasks involving cleaning of equipment, especially using damp rags, was associated with decreased wood dust particulate levels.

In the final multivariate models, workers with work-related ocular-nasal and asthma symptoms were more likely to have received training on dust control measures, which appeared counter-intuitive. Due to the cross-sectional nature of this study, temporality could not be established, and as a result the effect of training could not be established. However, it is probable that training was provided subsequent to the high prevalence of work-related respiratory symptoms reported by the workers.

8.1.4 EXPOSURE- RESPONSE RELATIONSHIPS

Despite the various studies exploring dose-response relationships in wood workers, few studies have undertaken a comprehensive approach using multiple exposure indices in relation to work-related asthma among workers exposed to specific tropical woods similar to what is used in the Mozambiquan wood processing industry. Furthermore, in addition to the traditional approaches in assessing work-related asthma, more recent studies have suggested the use of multiple clinical endpoints present in different asthma phenotypes (25, 32). Given these considerations, this study assessed exposure-response relationships between inhalable wood dust particulate exposures and work-related asthma, using multiple exposure metrics (current and cumulative exposure) and clinical indices of asthma (work-related respiratory symptoms, airway obstruction, bronchial reversibility and fractional exhaled nitric oxide) (**Chapter 7**).

In this study work-related ocular-nasal symptoms were associated with current inhalable dust exposures, with at least a threefold increased risk in a dose-dependent manner. Interestingly, work-related ocular-nasal symptoms were negatively associated with cumulative exposure. This may be related to a healthy worker effect, in that symptomatic workers are likely to change jobs by moving from high to less dusty areas due to their symptoms. With regard to work-related chest symptoms, these were positively associated with increasing levels of cumulative dust exposure. A consistent dose-response trend across all quartiles (Q2, OR= 1.00, 95% CI: 0.39 – 2.54; Q3, OR= 1.20, 95% CI: 0.49 – 2.95; Q3, OR= 1.94, 95 CI: 0.83 – 4.52) was observed, although not statistically significant. Similar dose-response relationships have been observed in other studies of wood workers (34, 35).

In present study, increasing levels of bronchial reversibility was positively associated with current inhalable dust particulate exposures based using more than one exposure metric (job titles, actual dust levels), suggesting an acute irritative response, although an allergic response cannot be entirely excluded. While this trend with bronchial reversibility was not observed using cumulative dust exposure metrics in multivariate models, a negative trend was observed with the post- bronchodilator ratio in a dose dependent manner. However, due to the lack of power, these associations were not statistically significant in the multivariate models. These findings are consistent with various other studies, both in cross-sectional and longitudinal, that have demonstrated exposure-response relationships in relation to decline in lung function indices among wood workers in different settings (29, 36, 37, 38, 39).

In exposure-response relationships exploring airway inflammation, fractional exhaled nitric oxide (FeNO) was positively associated with cumulative dust exposure in the unadjusted models. However, while the positive association persisted in adjusted models, it was not statistically significant for all quartiles, probably due to a lack of power. Using a higher cut-off for FeNO>50ppb, which is highly suggestive of allergic airway inflammation, the odds ratios increased two to three-fold across all quartiles. These findings suggest possible underlying chronic airway inflammation in workers with long-term wood dust exposures. To our knowledge, this is the first study to demonstrate such a relationship in wood workers. Similar findings have been reported in workers exposed to plant derived dusts by van der Walt et al. (40) in which a positive trend was observed between airborne spice dust particulate and serial changes in FeNO.

Overall, the findings of this current study suggest a predominant acute irritant dose-response relationship related to work-related ocular-nasal and asthma symptoms as well as bronchial reversibility patterns given the relatively high levels of dust produced in in wood processing and possible underlying chronic airway inflammation due to chronic wood dust exposures.
The findings of this study has demonstrated positive exposure-response relationships between inhalable particulate wood dust exposures generated during work activities and work-related ocular-nasal symptoms and asthma of a more acute irritant nature and associated with possible chronic airway inflammation due to toxins (endotoxins and mycotoxins) and undetected allergens associated with the wood dust.

8.2. STRENGTHS AND LIMITATIONS

8.2.1. STRENGTHS

There are a number of strengths that have been mentioned in relation to this study, that have contributed to the findings reported.

With regard to the exposure assessment, it investigated a number of exposure predictors for different components of wood dust (particulate, endotoxin and glucans) as well as the impact of processing various species of exotic wood. Additionally, the study design also considered geographical distribution of the factories (inland versus coastal) to take into consideration whether this would impact on the concentration of the different dust components measured. The exposure assessments also included a component of repeated measurements of workers, which enabled assessment of intra-individual variation of wood dust exposures. Furthermore, two multivariate modelling approaches (generalized linear model and generalized estimation equation) were used to assess exposure determinants to take into account these environmental sampling approaches, which contributed to the robustness of the findings. This is one of few studies that has studied both endotoxin and glucan exposures in the wood processing industry and, to the best of our knowledge, the first in Africa to undertake all these aspects.

With regard to the clinical endpoints measured, the study went beyond the study of respiratory symptoms to include more objective markers such as spirometry accompanied with bronchial reversibility as well as fractional exhaled nitric oxide to assess the presence of asthma. Furthermore, the bronchodilator response was analysed statistically using two approaches to obtain a better range of potential bronchial reversibility responses, since more traditional approaches could underestimate its presence in older workers (25). Furthermore, the use of exhaled nitric oxide levels to study airway inflammation is also a novel component of the study. To the best of our knowledge, this is the first epidemiological study to assess the prevalence of asthma and rhinitis among Mozambiquan wood workers.

Furthermore, this study has done a comprehensive assessment of environmental and host-associated risk factors to study exposure-response relationships in wood processing workers. To our knowledge, this is the first study to report on inhalational exposure to certain wood species, Missanda (*Erythrophleum suaveolens Brenan*), Panga-panga (*Millettia Stuhlmannii* Taub) and Mahogany bean (*Afzelia quanzensis Welw.*) and Mutondo (Cordyla Africana) as being associated with work-related ocular-nasal and asthma symptoms. Furthermore, the use of more objective markers for airway inflammation in the absence of tests for allergy being available accompanied by other lung function indices of asthma, in relation to exposure metrics for both current exposure (based on job title and actual dust levels) and cumulative exposures, enabled the study of both acute and chronic airway responses to assess dose-response relationships.

8.2.2. LIMITATIONS

Despite the aforementioned strengths, there were also limitations that need to be considered in the interpretation of the results. In the exposure assessment component, the limited number of samples may have affected the power of study to identify other exposure determinants. Furthermore, information on building characteristics was reliant on information obtained from the factories could not be totally validated for logistical reasons, which may have led to reporting bias. While the focus of the exposures was on dust particulate, exposure to other agents such as wood allergens, terpenes, and tannins were not measured due to logistical reasons. The same was applicable for the absence of other sensitive measures for assessing asthma using tests for bronchial hyperresponsiveness (methacholine or histamine challenge) and tests for specific allergic responses to wood species that could not be done due to field and laboratory constraints. In addition, the cross-sectional nature of the study did not allow for more detailed investigations to establish the temporality between exposure and asthma outcomes. There is also a possibility that a healthy worker effect may have been present, which may have underestimated the disease burden in this group of workers. While the possibility of sampling bias cannot be completely excluded, it is unlikely due to the very high (88%) response rate in this study.

8.3. RECOMMENDATIONS

In the light of the major findings of the excessively high dust levels observed in this study, key wood dust mitigation strategies need to be developed and pursued by the wood industry in partnership with the participating factories in order to reduce the respiratory health risks among wood processing workers in Mozambique.

8.3.1 Workplace control measures

Control of wood dust exposure can be achieved by implementing different dust control measures using the hierarchy of strategies commonly applied in workplace settings. These include elimination, substitution, engineering controls, administrative controls and appropriate personal protective equipment (PPE) (41).

Elimination and Substitution

Elimination is the most effective means to control a particular risk. Should elimination not be possible, substitution of hazardous agents with less hazardous or non-hazardous agents is preferred.

In the current study, exposure to African sandalwood and mahogany bean wood species were associated with higher inhalable dust particulates, endotoxin and β-glucan exposure. Furthermore, working with Missanda (*Erythrophleum suaveolens Brenan*), Panga-panga (*Millettia Stuhlmannii Taub*) and Mahogany bean (*Afzelia quanzensis Welw.*) was associated with work-related ocular nasal symptoms, while Mutondo (Cordyla Africana) was associated with both work-related ocular nasal symptoms and work-related asthma symptoms. While elimination of exposure to these wood species may be contemplated, the findings of this study would need to be replicated in order for this to be promoted as another strategy.

In this study, working with glues were also associated with airway inflammation On reviewing the common types of glues used in the Mozambiquan wood processing industry, the safety data sheets indicate that most of these products are mainly irritant in nature aside from the resin, Polyvinyl Formal (polyvinyl alcohol with formaldehyde). It is well known that exposure to formaldehyde is associated with respiratory symptoms such as irritation, allergies and asthma (42, 43), although this was not formally evaluated in the current study. It is recommended that replacement of glues with high formaldehyde content with non-formaldehyde containing glues or those with lower formaldehyde content (e.g. Gorilla Glue 5044181,Titebond III Ultimate Wood Glue), be considered to reduce the risk of additional airway symptoms in exposed workers.

Engineering controls

Engineering controls include design measures that are built into the design of a plant, its equipment or work processes to minimize exposure to the hazard. Engineering controls are a reliable means to control worker exposures provided that the controls are designed, used and maintained adequately.

In this study, both the building characteristics (closed and semi-closed buildings) as well as certain work processes (sawing, painting, carpentry and machinery) were associated with elevated dust particulate, glucan and endotoxin exposures. The study also demonstrated that local exhausted ventilation and larger and open buildings were associated with lower wood dust exposures. Various engineering control measures have been proposed to address these aspects (44). In the current context, the use of larger and more open design buildings could be a consideration given the relatively good climatic conditions experienced in this region. Furthermore, machine enclosure; use of local exhaust ventilation for machines and tools by equipping woodworking machines and handheld power tools with vacuum or exhaust systems; and installing adequate general ventilation with appropriate filters and ducts that are regularly maintained should be pursued.

Administrative controls

Administrative controls comprise the creation of standards and procedures that need to be followed while conducting certain tasks. These measures become increasingly important when the methods outlined above do not appear to be adequate, guaranteed or possible to implement.

This study demonstrated that general cleaning activities and using compressed air for cleaning, were associated with higher dust levels as well asevidence of airway inflammation. Furthermore, less frequent laundering of working clothes were also associated with higher dust levels. On other hand, daily sharpening of cutting tools, using dump rags for cleaning surfaces and floors twice during the working day were associated with lower dust levels. Cleaning equipment was also associated with lower asthma symptom scores and less frequent work-related ocular-nasal symptoms.Studies in other settings have also shown that workplace education and training programs have a positive impact on health and safety behaviors, and they need to be combined with other control measures to have positive impacts on worker health (45, 46).

Given the current study findings it is recommended that equipment and tools are regularly maintained and sharpened; routine use of compressed air for cleaning is avoided; surfaces and floors are free of wood chips and dust through regular cleaning methods using damp clean-up methods or vacuum cleaners; clothing is stored in dust free lockers and washed regularly; and an ongoing occupational health and safety training programs is implemented in these factories.

Personal protective equipment (PPE)

Personal protective equipment is the last measure in hierarchy of workplace control measures. They are useful for emergency situations, as an interim measure while installing more longstanding control measures and to supplement other control measures.

In the current study, the protective health effect of personal protective equipment was inconsistent. This was probably due to inappropriate PPE being used (without consideration to degree of filtration required), most workers used the same polypropylene masks for several days, and storage was sub-optimal. However, other studies have shown that the prevalence of respiratory symptoms in workers who used respiratory protective equipment was lower(47, 48). Importantly, inappropriate respirators in terms of efficient particle filtration and poor facial fit are unlikely to provide effective respiratory protection (49).

In the light of these findings it is recommended that appropriate half-face or full-face respirators with appropriate filter cartridges for wood dust be used (e.g. 3M 6200 half face piece reusable respirator, 3M 2091 6000 Series NIOSH Approved 2091 P100 Respirator, 3M Safety 142-6800 Safety Reusable Full Face Mask Respirator); non-approved paper dust masks be avoided (50); an alternative to aprons be used; and PPE is stored in clean dust-free lockers.

8.3.2 Medical surveillance programs

Medical surveillance is an important means of secondary prevention to be used when primary prevention measures have not been fully instituted or to assess the effectiveness of these primary preventive measures. This will ultimately enable early identification of affected workers relatively early in their employment and inform redeployment strategies and removal from further exposure of affected workersThe information obtained from medical surveillance can also be used to inform changes in work practices, refine administrative control programs, modify training programs, and inform any changes to personal protective equipment that is being used or contemplated (51).

In this study, none of the factories employed any form of medical surveillance of the wood processing workers. It is recommended that medical surveillance programs of workers involved in wood processing should include preplacement and periodical surveillance when primary preventive measures have not been fully implemented. This can be done using a standardized questionnaire for work-related upper and lower respiratory symptoms and asthma as well as spirometry accompanied with bronchial reversibility testing. Newly employed workers should be monitored more frequently in the first two years of employment to detect occupational asthma at an early stage before it results in chronic lung function loss, permanent respiratory impairment and disability.

8.3.3 Future research

There is a need for improved exposure characterization studies with specific reference to the determination of allergens, terpenes and β-glucans measurement in order to provide improved international exposure standards for these agents. This study has also raised a number of unanswered questions that need to be addressed in future research studies. These include better insights into the pathophysiological mechanisms for wood dust associated asthma, determining the specific physical and chemical proprieties that distinguish Missanda (*Erythrophleum suaveolens Brenan*), Panga-panga (*Millettia Stuhlmannii Taub*), Mahogany bean (*Afzelia quanzensis Welw*.) and Mutondo (*Cordyla Africana*) wood from other tropical woods, which increase their potential to cause work-related ocular-nasal and asthma symptoms. Improved study designs that include cohort studies, will also enable a better understanding of the association between wood dust exposures and adverse respiratory health outcomes, such as asthma and chronic obstructive pulmonary disease.

8.4. CONCLUSION

This study of Mozambiquan wood processing workers has demonstrated that exposure to all wood dust components were above international standards. It has also demonstrated that current and cumulative wood dust exposure is likely to be associated with an increased risk of both ocular-nasal and asthma symptoms. Furthermore, processing of particular wood species that include Missanda (Erythrophleum suaveolens Brenan), Panga-panga (Millettia Stuhlmannii Taub.) and Mahogany bean (Afzelia quanzensis Welw.) and Mutondo (Cordyla Africana), appear to be associated with this increased risk of ocular-nasal and asthma symptoms.

8.5. REFERENCES

1. Asgedom AA, Bråtveit M, Schlünssen V, Moen BE. Exposure to inhalable dust, endotoxin and formaldehyde in factories processing particleboards from eucalyptus trees in Ethiopia. Env Occup Heal Pract. 2020;1–10.
2. Afanou KA, Eduard W, Laier Johnsen HB, Straumfors A. Fungal fragments and fungal aerosol composition in sawmills. Ann Work Expo Heal. 2018;62(5):559–70.
3. Straumfors A, Olsen R, Daae AA, Afanou E, et al. Exposure to wood dust, microbial components, and terpenes in the Norwegian sawmill industry. Ann Work Expo Heal. 2018;20(20):1–15.
4. Ayalew E, Gebre Y, De Wael K. A survey of occupational exposure to inhalable wood dust among workers in small-and medium-scale wood-processing enterprises in Ethiopia. Ann Occup Hyg. 2015;59(2):253–7.
5. Jacobsen GH, Schlünssen V, Schaumburg I, Sigsgaard T. Cross-shift and longitudinal changes in FEV1 among wood dust exposed workers. Occup Environ Med. 2013;70(1):22–8.
6. Gioffrè A, Marramao A, Iannò A. Airborne microorganisms, endotoxin, and dust concentration in wood factories in Italy. Ann Occup Hyg. 2012;56(2):161–9.
7. Hagström K, Axelsson S, Arvidsson H, Bryngelsson I, Eriksson K, Hagstr K. Exposure to wood dust , resin acids , and volatile organic compounds during production of wood pellets. J Occup Environ Hyg. 2008;5:296–304.

8. Osman E, Pala K. Occupational exposure to wood dust and health effects on the respiratory system in a minor industrial estate in Bursa, Turkey. Int J Occup Med Environ Health. 2009;22(1):43–50.
9. Rongo LMB, Msamanga GI, Burstyn I, Barten F, Dolmans WM V, Heederik D. Exposure to wood dust and endotoxin in small-scale wood industries in Tanzania. J Expo Anal Environ Epidemiol. 2004;14(7):544–50.
10. Fox FH. An Epidemiological Survey of Asthma in a Pine Sawmill in South Africa. 2004.
11. Rongo LMB, Besselink A, Msamanga GI, Dolmans WM V, Demers PA, Heederik D. Respiratory symptoms and dust exposure among male workers in small-scale wood industries in Tanzania. J Occup Environ Med. 2002;44(12):1153–60.
12. Shamssain MH. Pulmonary function and symptoms in workers exposed to wood dust. Thorax. 1992;47(2):84–7.
13. Aguwa EN, Okeke T a, Asuzu MC. The prevalence of occupational asthma and rhinitis among woodworkers in south-eastern Nigeria. Tanzan Health Res Bull. 2007;9(1):52–5.
14. ACGIH. Threshold limit values (TLVs) and biological exposure indices (BEIs). 2012. 871–1130 p.
15. The Swedish Work Environment Authority. Occupational exposure limit values. 2011. 84 p.
16. Government NZ. Workplace exposure standards and biological exposure indices. 2018. 68 p.
17. Health Council of the Netherlands. Endotoxins health-based recommended occupational exposure limit. Publication no. 2010/04OSH. 2010. 100 p.
18. Rylander R. Indoor air-related effects and airborne (1→3)-β-D-Glucan. Environ Health Perspect. 1999;107(3):501–3.
19. Pekkanen J, Sunyer J, Anto JM, Burney P. Operational definitions of asthma in studies on its aetiology. Eur Respir J. 2005;26(1):28–35.
20. Sunyer J, Pekkanen J, Svanes C, Janson C, Marco R De, Burney P. Asthma score : predictive ability and risk factors. Allergy. 2007;62:142–8.
21. Sá-Sousa A, Pereira AM, Almeida R, Araújo L, Couto M, Jacinto T, et al. Adult asthma scores—development and validation of multivariable scores to identify asthma in surveys. J Allergy Clin Immunol Pract. 2019;7(1):183-190.e6.
22. Bjermer L, Alving K, Diamant Z, Magnussen H, Pavord I, Piacentini G, et al. Current evidence and future research needs for FeNO measurement in respiratory diseases. Respir Med. 2014;108(6):830–41.

23. Dweik RA, Boggs PB, Erzurum SC, et al. Use of exhaled nitric oxide measurement to identify a reactive, at-risk phenotype among patients with asthma. Am J Respir Crit Care Med. 2010;181(10):1033–41.
24. American Thoracic Society. Function Testing : Selection of reference values and interpretative strategies. Am Rev Respir Dis. 1991;144(5):1202–18.
25. Tuomisto LE, Ilmarinen P, Lehtimäki L, Tommola M, Kankaanranta H. Immediate bronchodilator response in FEV_1 as a diagnostic criterion for adult asthma. Eur Respir J. 2019;53(2):1–7.
26. Schlunssen V, Schaumburg I, Heederik D, Taudorf E, Sigsgaard T. Indices of asthma among atopic and non-atopic woodworkers. Occup Environ Med. 2004;61(6):504–11.
27. Talini D, Monteverdi A, Benvenuti A, Petrozzino M, Di Pede F, Lemmi M, et al. Asthma-like symptoms, atopy, and bronchial responsiveness in furniture workers. Occup Environ Med. 1998;55(11):786–91.
28. Tobin EA, Ediagbonya TF, Okojie OH, Asogun DA. Occupational exposure to wood dust and respiratory health status of sawmill workers in South-South Nigeria. Pollution Effects & Control. 2016;4(1):4–9.
29. Bolund ACS, Miller MR, Jacobsen GH, Sigsgaard T, Schlünssen V. New-onset COPD and decline in lung function among wood dust-exposed workers : Re-analysis of a 6-year Follow-up Study. Ann Work Expo Heal. 2018;20(20):1–13.
30. Mumuni M. Respiratory Health Problems Among Sawmill Workers At the Timber Market, Accra. University of Ghana; 2015.
31. Paraskevaidou K, Porpodis K, Kontakiotis T, Kioumis I, Spyratos D, Papakosta D. Asthma and rhinitis in Greek furniture workers. J Asthma. 2019;1–10.
32. Coman I, Lemie C. Fractional Exhaled Nitric Oxide (FeNO) in the Screening and diagnosis work-up of occupational asthma. curr treat options allergy. 2017;4:145–59.
33. Meo SA. Effects of duration of exposure to wood dust on peak expiratory flow rate among workers in small scale wood industries. Int J Occup Med Environ Health. 2004;17(4):451–5.
34. Schlünssen V, Schaumburg I, Taudorf E, Mikkelsen AB, Sigsgaard T. Respiratory symptoms and lung function among Danish woodworkers. J Occup Environ Med. 2002;44(1):82–98.
35. Sripaiboonkij P, Phanprasit W, Jaakkola MS. Respiratory and skin effects of exposure to wood dust from the rubber tree Hevea brasiliensis. Occup Environ Med. 2009;66(7):442–7.

36. Jacobsen G, Schlünssen V, Schaumburg I, Sigsgaard T. Increased incidence of respiratory symptoms among female woodworkers exposed to dry wood. Eur Respir J. 2009;33(6):1268–76.
37. Noertjojo HK, Dimich-Ward H, Peelen S, Dittrik M, Kennedy SM, Chan-Yeung M. Western red cedar dust exposure and lung function: A dose-response relationship. Pneumologie. 1997;51(12):141–6.
38. Mandryk J, Alwis KU, Hocking AD. Work-related symptoms and dose-response relationships for personal exposures and pulmonary function among woodworkers. Am J Ind Med. 1999;35(5):481–90.
39. Teschke K, Spierings J, Marion SA, Demers PA, Davies HW, Kennedy SM. Reducing attenuation in exposure-response relationships by exposure modeling and grouping: The relationship between wood dust exposure and lung function. Am J Ind Med. 2004;46(6):663–7.
40. Van Der Walt A, Singh T, Baatjies R, Lopata AL, Jeebhay MF. Work-related allergic respiratory disease and asthma in spice mill workers is associated with inhalant chili pepper and garlic exposures. Occup Environ Med. 2013;70(7):446–52.
41. Heederik D, Henneberger PK, Redlich CA. Primary prevention: exposure reduction, skin exposure and respiratory protection. Eur Respir Rev. 2012;21(124):112–24.
42. Thetkathuek A, Yingratanasuk T, Ekburanawat W. Respiratory symptoms due to occupational exposure to formaldehyde and MDF Dust in a MDF Furniture Factory in Eastern Thailand. Adv Prev Med. 2016;2016:1–11.
43. Mathur N, Rastogi SK. Respiratory effects due to occupational exposure to formaldehyde: Systematic review with meta-analysis. Indian J Occup Environ Med. 2007;11(1):26.
44. California Department of Public Health. Wood Dust and Work-related Asthma. 2017.
45. Robson LS, Stephenson CM, Schulte PA, Amick BC, Irvin EL, Eggerth DE, et al. A systematic review of the effectiveness of occupational health and safety training. Scand J Work Environ Health. 2012;38(3):193–208.
46. Cohen A, Colligan MJ, Sinclair R, Newman J, Schuler R. Assessing occupational safety and health training: A literature review. Cincinnati, OH Natl Institutes Heal. 1998;1–174.
47. Sunaryo M. The Effect of environmental factor and use of personal protective equipment on the symptoms of acute respiratory tract infections in furniture industry workers. Indones J Med Lab Sci Tecnol. 2013;53(9):1689–99.
48. Lastri P, Dewata I, Sari M. The relationship between work period and use of personal protective equipment with respiratory disorder complaints in brick craftsman in Sintuk

Toboh Gadang District Padang Pariaman Regency 2017. IOP Conf Ser Earth Environ Sci. 2019;314:6.
49. Wcherrie J, Apsley A, Cowie H, Steinle S, Mueller W, Lin C, et al. Effectiveness of face masks used to protect Beijing residents against particulate air pollution. Occup Environ Med. 2018;75(6):446–52.
50. Occupational Safety and Health Administration. Small entity compliance guide for the respiratory protection standard. 2011. 120 p.
51. Conway H, Simmons J, Talbert T. The purposes of occupational medical surveillance in US industry and related health findings. Journal of Occupational Medicine. 1993;35 (7):670–86.

APPENDICES

Appendix 1A: English Consent form

UCT/UEM - WORK- RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY – 2016/7
HREC ERF: 543/206

CONSENT FORM

1. **Title of research project**

   Work-related asthma among workers in the Mozambique wood processing industry

2. **Purpose of the research**

   There has not been any published research in Mozambique relating to asthma in workers exposed to wood dust - this study would be the first to provide such data. The results of the study will be used to design a prevention and control strategy for wood dust exposure for workers at risk of work-related respiratory disease in the timber and wood industry. Furthermore, the study results will also highlight the adequacy of exposure standards for occupational asthma among wood workers in Mozambique.

3. **Description of the research project**

   If you agree to participate in this study you will be asked to complete a questionnaire, which will provide us with important information on respiratory symptoms and other medical conditions as well as your employment history. During the course of the study a doctor or nurse will use sterile (free of germs) equipment to take 10ml (~2 teaspoons) of blood to be tested if you have allergy. A doctor or trained nurse will test the strength of your lungs by doing some breathing tests (Spirometry). You will be asked to blow several times into a machine which measures how well your lungs are working. You will be asked to repeat the breathing test after you first breathe in a small amount of a medication (salbutamol). This test helps us find out if you may have a breathing problem like asthma. You will also be asked to blow 2 times into a NIOXMINO machine, which measures nitric oxide produced by the airways. This machine is used to detect if a person has allergic airway inflammation which is present in asthma or rhinitis.

   You will wear a personal sampling pump connected to a filter for a minimum duration of 4 hours while performing your daily duties so that we can collect the air in your breathing zone to test if you are exposed to hazardous agents in the wood dust.

4. **Confidentiality of information collected**

   Your name will not appear on any reports or data collection forms. The records of blood tests, questionnaires and breathing tests will be kept completely confidential and will be seen only by members of the study team.

5. **Risks and discomforts of the research**

   a) **From the questionnaire:** Some of the research questions may make you uncomfortable; however, we have trained our interviewer to be as sensitive when asking these questions. You may be concerned about confidentiality of the information that you provide; however, we have taken precautions to minimize this risk.

b) **From the blood tests**: You will feel a single needle stick when the blood is taken. Sometimes a small bruise may occur from the needle stick. The total amount of blood taken is quite small and your body will quickly replace it.

c) **From breathing tests:** There is a small chance that the initial breathing test could cause you to become light-headed or faint. Having you complete the test in a seated position under the observation of trained personnel greatly reduces the chance of your having such a problem. You will be given medicine (salbutamol) to breathe in that works to open your lungs. Although very rare, this medication can briefly cause a fast heartbeat, tremor, nervousness or chest pain. A doctor or nurse will always be available in case of any emergency.

d) **From wearing dust measuring equipment**: Wearing the dust measuring equipment is not a risk to you and it will not interfere with your work.

6. **Expected benefits to you and to others**

The indirect benefit of the study is creating a safer and healthy working environment for you and your fellow workers. All participants will be given a written copy of their laboratory test results and what they mean and at the end of the study we will present our findings to the company and the worker representatives. All workers with abnormal results will be offered referral to the Pneumologist of Central Hospital of Maputo or Beira for further evaluation. Where the disease is not considered to be work-related, they will be referred to a general practitioner at the Health Centre for further evaluation and-/or treatment. Should the disease be confirmed, a worker's compensation claim will be submitted and relocation will be advised based on the Labour law in Mozambique.

7. **Costs to you resulting from participation in the study**

The study is offered at no cost to you. In the event a problem is discovered and you wish to be seen by a doctor for it, we can recommend to you who to see. However, the study cannot pay for these additional medical visits or treatments.

8. **Contact person/s**

You may contact one of the following persons for answers to further questions about the research, your rights, or any injury you may feel is related to the study.

University of Cape Town Researchers:
Prof. Mohamed Jeebhay, Telephone No. (021) 406-6309
Dr Roslynn Baatjies, Telephone No.

Eduardo Mondlane University Researchers:
Prof. Elizabete Nunes, Telephone No. (258) 82 31 02 470
Dr. Paulino Chamba, Telephone No. (258) 84 01 45 307

University of Cape Town Human Research Ethics Committee (HREC):
Prof. Marc Blockman (021) 406-6492

University of Michigan Medical School Institutional Review Board (IRBMED)
Telephone No. 001-734-763-4768; E-mail: irbmed@umich.edu
2800 Plymouth Road, Building 520, Room 3214, Ann Arbor, Michigan 48105 (USA)

Ministry of Health of Mozambique Bioethics Committee

Dr João Fernando Lima Schwalbach, Av. Eduardo Mondlane/Salvador Allende. Maputo – Mozambique. PB 264, Telephones No. 43 30 814 / 42 27 131 (4). Telex: 6 – 239 MISAU MO. Fax: 258 (1) 42 65 47, 258 (1) 33 320. Cell: 82 40 66 350

UCT/UEM - WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY – 2016/7
HREC REF: 543/2016

CONSENT FORM

STUDY NO. _______________

9. **Consent of the participant**

I have read the information given above, or it has been read to me. I understand the meaning of this information, Dr./Mr./Ms. ____ has offered to answer any questions concerning the study. By signing this form, I hereby consent to participate in the study. I also understand that I am free to withdraw from the study at any time without penalty.

10. **Documentation of the consent**

One copy of this signed document will be kept together with our research records for this study. A copy of the information sheet about the study will be given to you to keep.

___________________________________	______________________________
Printed name of participant	Signature, Mark, or Thumb Print
________________________________	____________________________
Interviewer’s name (Print)	Signature

DATE: ____________________

Appendix 1B: Portuguese Consent form

UCT/UEM – ASMA RELACIONADA AO TRABALHO ENTRE OS TRABALHADORES DA INDÚSTRIA DE PROCESSAMENTO DE MADEIRA EM MOÇAMBIQUE– 2017

FOLHA DE CONSENTIMENTO

1. **Título do projecto de pesquisa**

   Asma relacinada ao trabalho entre os trabalhadores da indústria de processamento de madeira em Moçambique

2. **Propósito da pesquisa**

   Não há qualquer estudo publicado em Moçambique relativo à asma em trabalhadores expostos a poeira de madeira - este seria o primeiro a fornecer tais dados. Os resultados do estudo serão usados para criar uma estratégia de prevenção e controle da exposição a poeira de madeira para os trabalhadores em risco de doenças respiratórias relacionadas ao trabalho na indústria de processamento de madeira. Além disso, os resultados do estudo irão também chamar a atenção sobre a necessidade de adequação das normas de exposição para asma ocupacional entre trabalhadores de madeira em Moçambique.

3. **Descrição do projecto de pesquisa**

   Se você aceitar a participar neste estudo será pedido a completar um questionário, que irá fornecer-nos informações importantes sobre sintomas respiratórios e outras condições médicas assim como a sua história ocupacional. No decurso do curso do estudo o médico ou a enfermeira irá usar equipamento esterilizado (livre de germes) para colher 10 ml (~ 2 colheres de chá) de sangue para ser testado se você tem alergia. O médico ou enfermeira teinada irá testar a força dos seus pulmões fazendo alguns testes respiratórios (Espirometria). Você será pedido a soprar várias vezes na máquina que mede quão bem funcionam os seus pulmões. Será pedido a repetir o teste respiratório depois de primeiro respirar numa pequena quantidade de medicamento (salbutamol).

   Este teste ajuda-nos a descobrir se você tem problemas respiratórios como asma. Você será também pedido a soprar 2 vezes na máquina NIOXMINO, que mede o óxido nítrico produzido pelas vias aéreas. Esta máquina é usada para detectar se a pessoa tem inflamação alérgica das vias aéreas presente na asma e renite.

   Você irá usar uma bomba de amostragem individual conectado a um filtro com uma duração minima de 4 horas enquanto executa as suas actividades diárias para que possamos colectar o ar na sua zona respiratória para testar se você está exposto a agentes perigosos da poeira da madeira. Iremos colher uma pequena quantidade de urina num frasco para que a possamos testar para ver algum terpeno está presente.

4. **Confidencialidade da informação coletada**

   O seu nome não irá aparecer em nenhum relatório ou ficha de coleta de dados. Os registos dos testes de sangue, questionários e testes respiratórios serão mantidos completamente confidenciais e serão vistos apenas pelos membros da equipa de pesquisa.

5. **Riscos e desconfortos do estudo**

a) **Do questionário:** Algumas perguntas de pesquisa podem deixá-lo desconfortável; no entanto, treinamos o nosso entrevistador para ser sensível quando estiver fazendo essas perguntas. Poderá estar preocupado com a confidencialidade da informação que fornece; no entatnto tomamos precauções para minimizar este risco.

b) **Dos testes de sangue**: Você poderá sentir uma ligeira dor quando o sangue for colhido. Algumas vezes pequeno hematoma pode ocorrer no local. A quantidade total de sangue tomado é muito pequena e seu corpo irá substituí-lo rapidamente.

c) **Dos testes respiratórios:** Há uma pequena chance de o teste respiratório inicial poder causar lhe dor de cabeça ou desmaio. Fazendo o teste na posição de sentado sob a observação de pessoal treinado minimiza consideravelmente a chance de tal acontecer. Será dado um medicamento (salbutamol) para respirar que serve para abrir os seus pulmões. Apesar de ser muito raro, este medicamento pode momentaneamente causar palpitações cardícas, tremor, nervosismo ou dor do peito. O médico ou a enfermeira estarão sempre a disposição para qualquer emergência.

d) **Do uso do equipamento de medição da poeira**: O uso do equipamento de medição da poeira não representa um risco para si e não irá interferir no seu trabalho.

6. **Benefícios esperados para si e para os outros**

O benefício indirecto do estudo é criar um ambiente de trabalho seguro e saudável para si e seus colegas de trabalho. Todos os participantes receberão uma cópia escrita dos resultados dos seus testes laboratoriais com sua interpretação e, no final do estudo, iremos apresentar as nossas conclusões á empresa e aos representantes dos trabalhadores. Todos os trabalhadores com resultados anormais serão referidos ao Pneumologista do Hospital Central de Maputo ou Beira para a melhor avaliação. Os trabalhadores cuja a doença for considerada como não sendo relacionada ao trabalho serão referidos ao clínico geral no Centro de Saúde para a subsequente avaliação e/ou tratamento. Sendo a doença confirmada como sendo relacionada ao trabalho será submetido um pedido de compensação do trabalhador e recomendada a recolocação do mesmo de acordo com a legislação laboral vigente em Moçambique.

7. **Custos e benefícios resultantes da sua participação no estudo**

O estudo é lhe oferecido sem custos para si. No caso de ser detectado algum problema e desejar para o efeito ter uma consulta médica, nós podemos o recomendar quem o possa observar. Contudo, o estudo não poderá pagar por estas consultas e tratamentos adicionais.

8. **Pessoa/s de contacto**

Você poderá contactar uma da seguintes pessoas para respostas a questões ulteriores sobre a pesquisa, seus direitos, ou se sentir que alguma lesão possa estar relacionada com o estudo.

Investigadores da Universidade de Cape Town:
Prof. Mohamed Jeebhay, Telefone No. (021) 406-6309
Dr Roslynn Baatjies, Telephone No.

Investigadores da Universidade Eduardo Mondlane:

Prof. Elizabete Nunes, Telefone No. (258) 82 31 02 470
Dr. Paulino Chamba, Telefone No. (258) 84 01 45 307

Comité de Bioética de Pesquisa em Humanos da Universidade de Cape Town (HREC):
Prof. Marc Blockman (021) 406-6492

Conselho de Revisão Institucional da Faculdade de Medicina da Universidade de Michigan (IRBMED)
Telefone No. 001-734-763-4768; E-mail: irbmed@umich.edu
2800 Plymouth Road, Building 520, Room 3214, Ann Arbor, Michigan 48105 (USA)

Comité de Bioética do Ministério da Saúde de Moçambique
Dr João Fernando Lima Schwalbach, Av. Eduardo Mondlane/Salvador Allende. Maputo – Mozambique. PB 264, Telefones No. 43 30 814 / 42 27 131 (4). Telex: 6 – 239 MISAU MO. Fax: 258 (1) 42 65 47, 258 (1) 33 320. Celular: 82 40 66 350

UCT/UEM – ASMA RELACIONADA AO TRABALHO ENTRE OS TRABALHADORES DA INDÚSTRIA DE PROCESSAMNTO DE MADEIRA EM MOÇAMBIQUE – 2017
HREC REF: 543/2016

FORMULÁRIO DE CONSENTIMETO

ESTUDO NO. _______________

9. **Consentimento do participante**

Eu lí a informação fornecida acima, ou esta foi me lida. Entendo o significado desta informação, o Dr/Sr./Sra. ____ofereceu-se a responder a todas as questões concernentes ao estudo. Ao assinar este formulário, concordei em participar no estudo.Também entendo que estou livre de sair do estudo a qualquer momento sem qualquer represália.

10. **Documentação do consentimento**

Uma cópia assinada deste documento será mantida nos nossos registos para este estudo. Uma cópia da folha de informação acerca do estudo será lhe dada para conservar.

_____________________________ _____________________________________
Nome impresso do participante Assinatura, Marca, ou impressão do polegar

_______________________________ ___________________________
Nome do entrevistador (impresso) Assinatura

DATA: ____________________

Appendix 2A: English pretest instructions

UCT/UEM
WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY – 2017

PRETEST INSTRUCTIONS

Surname: ____

First Name: ____

Work number of participant: _____________________________

YOUR VISIT/APPOINTMENT is at__________(time) on the______________ (date)

You will have the following tests on this visit:

1. A member of the research team will explain the study, obtain your permission to participate, and ask you a list of questions.
2. Members of the research team will conduct the lung function and NIOX tests.
3. A nurse will take a specimen of blood for the allergy test and obtain a urine sample from you on this visit.
4. Please bring this form with you when you come for testing.

Reason for doing these tests:

These tests will enable us to find out whether you are allergic to some of the things you are exposed to at work, such as wood dust, glucans, terpenes and mites in the bedding. In this way we will be able to find ways of protecting the health of workers working in the wood processing industry.

BEFORE YOU COME FOR TESTING IT IS VERY IMPORTANT THAT YOU FOLLOW THE INSTRUCTIONS BELOW TO ENSURE ACCURATE RESULTS.

1. **DO NOT** smoke any tobacco or cigarettes during the **2 hours** before your appointment.

2. Please ask your staff **NOT TO EAT/DRINK 1 HOUR** before their assessment.

3. We will start at **8: 00 AM**, please ask them to adhere to the above.

4. If you are taking asthma medicines:
   - Do not use any asthma tablets/syrup (for example Nuelin, Theodur, Euphyllin Retard) during the **24 hours (1 full day)** before your appointment.
   - Do not use any bronchodilator asthma inhaler pumps (for example Ventolin, Venteze, Asthavent, Atrovent), during the **12 hours** before your appointment.

5. If you are taking any medicine or using any skin cream for allergies (itchy nose/eyes/skin rash) or for flu (for example, Sinutab, Allergex, Actifed, Zyrtec):
   - Do not use any of these medicines for the **3 days** before your appointment since this may keep the allergy test from identifying which things you are allergic to.

6. Please bring with you on the visit any medicine/s from a doctor or clinic that you may be taking at the time to show it to the interviewer. Please bring the bottles or packets with you so that the interviewer can record the name of the medicine.

IF YOU FORGET OR FEEL YOU MUST USE YOUR MEDICINES, COME ANYWAY, WE WILL TALK WITH YOU AND DECIDE WHICH TESTS CAN BE DONE ON THAT DAY.

UCT/UEM - ASMA RELACIONADA AO TRABALHO ENTRE OS TRABALHADORES DA INDÚSTRIA DE PROCESSAMENTO DE MADEIRA EM MOÇAMBIQUE - 2017

INSTRUÇÕES PRETESTE

Apelido : ____

Primeiro Nome: ____

Número do trabalhador participante: _________________________

A SUA VISITA/CONSULTA é ás ________ (hora) em ____________ (data)

Nesta visita você terá os seguintes testes:

1. Um membro da equipa de investigação irá lhe explicar o estudo, pedir permissão para participar e fazer-lhe uma série de perguntas.
2. Membros da equipa de investigação levarão a cabo testes da função pulmonar e NIOX.
3. A enfermeira colherá de si nesta visita uma amostra de sangue para teste de alergia.
4. Por favor, traga consigo este impresso quando vier a testagem.

Razão para fazer estes testes:

Estes testes permitirão-nos descobrir se você é alérgico ás coisas a que está exposto no local de trabalho, tais como, poeira da Madeira, glucanos, terpenes e ácaros na roupa da cama. Desta forma seremos capazes de encontrar formas de proteger a saúde dos trabalhadores que trabalham na indústria de processamento de Madeira.

ANTES DE VIR PARA A TESTAGEM É MUITO IMPORTANTE QUE VOCÊ SIGA AS INSTRUÇÕES ABAIXO PARA GARANTIR A PRECISÃO DOS RESUTADOS.

1. **NÃO** fume qualquer tabaco ou cigarros durante as **2 horas** anteriores a consulta.

2. Por favor, **NÃO COMER/BEBER 1 HORA** antes da sua avaliação.

3. Começaremos às **8: 00 H**, por favor peço-lhe para aderir ao acima.

4. Se está a tomar medicamentos de asma:
   - Não use nenhum comprimido/xarope para asma (por exemplo Aminofilina, Salbutamol, Nuelin, Theodur, Euphyllin Retarda) durante as **24 horas (1 dia inteiro) anteriores à sua consulta**.
   - Não use nenhum inalador pressurizado com acção broncodilatadora (por exemplo Salbutamol, ou Brometo de Ipatropio), durante as **12 horas** anteriores à sua consulta.

5. Se está a tomar algum medicamento ou usar algum creme cutâneo para alergias (prurido nasal/ocular/erupção cutânea) ou para gripe (por exemplo, clorfeniramina, Sinutab, loratadine):
   - Não use nenhum desses medicamentos durante os **3 dias** anteriores à consulta já que isso interfere no resultado dos testes de alergia..

6. Por favor traga consigo qualquer medicamento que esteja a tomar para mostrar o entervistador.

SE SE ESQUECER OU SENTIR QUE TEM DE TOMAR OS SEUS MEDICAMENTOS NESSE DIA, VENHA MESMO ASSIM, CONVERSAREMOS CONSIGO E DECIDIREMOS QUE TESTES PODEM SER FEITOS

Appendix 3A: English Questionnaire

UCT/UEM WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY - 2017

ENGLISH QUESTIONNAIRE

Note: Answer ALL questions. Insert a cross (X) where appropriate

Survey Number

Employer/Company name:

Site or location:

Province

1	Surname						
3	First name/s						
3	Address						
4	Work number						
5	Date of birth:	Day		Month		Year	
6	Gender:					Male	
						Female	
7	Home Language:					Portuguese	
						Ronga	
						Changana	
						Sena	
						Ndau	
						Other	
8	Are you a casual or permanent worker?					Casual	
						Permanent	
9	Employment contract					Day	
						Nigth	
10	Work schudele/shift	______________________					
11	Last work day?	Day		Month		Year	

B. HEALTH PROBLEMS

Wheeze and tightness in the chest

1	Have you ever had wheezing or whistling in your chest in the past?	Yes	
		No	
	If YES, go on to Question 1.1		
	If NO, skip to Question 2		
1.1	If yes, when was the first time you had these sy Month	Year	
1.2	Have you had wheezing or whistling in your chest at any time in the **last 12 months?**	Yes	
		No	
	If YES, go on to Question 1.2.1		
	If NO, skip to Question 3		
1.2.1	Have you been short of breath when the wheezing noise was present?	Yes	
		No	
1.2.2	Have you had this wheezing or whistling when you did not have a cold or flu?	Yes	
		No	
2	Have you been woken up with a feeling of tightness in your chest at any time in the **last 12 months?**	Yes	
		No	

Shortness of breath

3	Have you had an attack of shortness of breath that came on during the daytime when you were at rest at any time in the **last 12 months?**	Yes	
		No	
4	Have you had an attack of shortness of breath that came on following running or exercise at any time in the **last 12 months?**	Yes	
		No	
5	Have you been woken by an attack of shortness of breath at any time in the **last 12 months?**	Yes	
		No	

Cough and phlegm from the chest

6	Have you been woken by an attack of coughing at any time in the **last 12 months?**	Yes	
		No	
7	Do you usually cough first thing in the morning?	Yes	
		No	
8	Do you usually cough during the rest of the day, or at night?	Yes	
		No	
	If YES, go on to Question 8.1		
	If NO, skip to Question 9		
8.1	Do you cough like this on most days/nights for as much as three or more months in each of the last two years?	Yes	
		No	
9	Do you usually bring up any phlegm from your chest first thing in the morning?	Yes	
		No	

10	Do you usually bring up any phlegm from your chest during the day, or at night?	Yes ☐ No ☐
	If YES, go on to Question 10.1 ***If NO, skip to Question 11***	
10.1	Do you bring up phlegm like this on most days/ nights for as much as three or more months in each of the last two years?	Yes ☐ No ☐

Breathing

11	Do you ever have trouble with your breathing?	Yes ☐ No ☐
	If YES, go on to Question 11.1 ***If NO, skip to Question 12***	
11.1	Do you have this trouble:	
	Give all options at once ***Insert a cross (X) next to one answer only***	
	a) continuously so that your breathing is never quite right?	☐
	b) repeatedly, but it goes away completely between the times when it troubles you?	☐
	c) only rarely?	☐
12	Are you disabled from walking by a condition other than heart or lung disease?	Yes ☐ No ☐
	If YES, state the condition ___ ***and go on to Question 13*** ***If NO, go to Question 12.1***	
12.1	Are you troubled by shortness of breath when hurrying on level ground or walking up a slight hill?	Yes ☐ No ☐
	If YES, go on to Question 12.1.1 ***If NO, skip to Question 13***	
12.1.1	Do you get short of breath walking with other people of your own age on level ground?	Yes ☐ No ☐
12.1.2	Do you have to stop for breath when walking at your own pace on level ground?	Yes ☐ No ☐

Asthma

13	Have you ever had asthma?	Yes ☐ No ☐
	If YES, go on to Question 13.1 ***If NO, skip to Question 13.8***	
13.1	If yes, was this confirmed by a doctor?	Yes ☐ No ☐

13.2 How old were you when you were told you have asthma?

<u>Give all options at once</u>
Insert a cross (X) next to one answer only

a) Only before you were 17 years old ☐
b) Only at the age of 17 years or older ☐
c) Both ☐

The following references to "attack" of asthma refers to episodes of wheezing, shortness of breath, chest tightness or cough attributed to asthma

13.3.1 How old were you when you had your first attack of asthma? years old ☐

13.3.2 How old were you when you had your most recent attack of asthma? years old ☐

13.4 Which Station of the year do you usually have attacks of asthma?

Answer ALL questions, insert a cross (X)

13.4.1	January/February	Yes	☐
		No	☐
13.4.2	March/April	Yes	☐
		No	☐
13.4.3	May/June	Yes	☐
		No	☐
13.4.4	July/August	Yes	☐
		No	☐
13.4.5	September/October	Yes	☐
		No	☐
13.4.6	November/December	Yes	☐
		No	☐
13.5	Have you had an attack of asthma in the last	Yes	☐
	12 months?	No	☐

If YES, go on to Question 13.5.1
If NO, skip to Question 13.6

13.5.1 How often have you had an attack of asthma in the **last 12 months?**

<u>Give all options at once</u>
Insert a cross (X) next to one answer only

a) Every day ☐
b) More than 2 times a week ☐
c) More than 1 time per month ☐
d) 3 to 12 times in the whole year ☐
e) 1 to 2 times in the whole year ☐

13.6	Are your chest symptoms caused by, or made worse by any of the following:	
	Answer all questions, insert a cross (X)	
13.6.1	Contact with animals/pets	Yes ☐ No ☐
13.6.2	Grass or flowers	Yes ☐ No ☐
13.6.3	Heavy exercise	Yes ☐ No ☐
13.6.4	Breathing cold air	Yes ☐ No ☐
13.6.5	Dusts or sprays at work	Yes ☐ No ☐
13.6.6	Tobacco smoke	Yes ☐ No ☐
13.6.7	Change in the weather	Yes ☐ No ☐
13.7	Do your chest symptoms seem better or worse when you are away from work (for example, on weekends, off-shift and annual leave)?	
	Give all options at once ***Insert a cross (X) next to ONE answer only***	
	a) Stay the same	☐
	b) Get better	☐
	c) Get worse	☐
13.8	Does being at work ever make your chest tight or wheezy?	Yes ☐ No ☐
	If YES, go on to Question 13.8.1 ***If NO, skip to Question 13.9***	
13.8.1	When did you first notice having problems with chest tightness or wheeze at work? Month ____	Year ____
13.8.2	Is there anything that you work with **(specific activities in wood processing facilities)** causes you to have these chest symptoms?	Yes ☐ No ☐
	If YES, go on to Question 13.8.3 ***If NO, skip to Question 13.9***	
13.8.3	Which type of wood do you think is causing these symptoms?	
	____	

13.9	Have you ever had to change or leave your work area, either temporarily or permanently, in this company or any other company because of any chest symptoms?	Yes ☐ No ☐
	If YES, go on to Question 13.9.1 ***If NO, skip to Question 13.10***	
13.9.1	What type of job were you doing when this happened?	
	______________________	
13.9.2	Was this job were you doing in this company?	Yes ☐ No ☐
	If YES, go on to Question 13.9.2.1 ***If NO, skip to Question 13.10***	
13.9.2.1	What area/section did you move to?	
	______________________	
13.9.2.2	What job did you do there?	
	______________________	
13.9.2.3	Did your symptoms improve when you changed jobs?	Yes ☐ No ☐
13.10	Have you ever worked in a job or jobs that exposed you to other than wood dust **(e.g. feed, litter, bedding, feathers)** or fum	Yes ☐ No ☐
	If YES, go on to Question 13.10.1. ***List the jobs beginning with the most recent*** ***If NO, skip to Question 13.11***	
13.10.1	What was or is this job?	______________________ (if current job write 'current job' and specify)
13.10.2	Before that?	______________________
13.11	Has there ever been **an instance** when you inhaled **a large amount** of vapour, gas or fumes in any of these jobs that resulted in you developing a tight chest, wheeze or cough?	Yes ☐ No ☐
	If YES, go on to Question 13.11.1. ***If NO, skip to Question 13.12***	
13.11.1	What was or is this job?	______________________ (if current job write 'current job' and specify)

13.12	Are you using any medicines, including inhalers/ pumps, nebulizers, syrups or tablets, for asthma or breathing problems?	Yes ☐ No ☐
	If YES, go on to Question 13.12.1, showing examples of each ***If NO, skip to question 13.13***	
13.12.1	Which medicines?	______ ______ ______
13.12.2	Do you take these medicines every day even when you do not have any trouble breathing?	Yes ☐ No ☐
13.13	Have you ever been treated for any of the following:	
	Answer all questions	
13.13.1	Repeated chest infections as a child	Yes ☐ No ☐ Unknown ☐
13.13.2	Tuberculosis (TB)	Yes ☐ No ☐ Unknown ☐
13.13.3	Chronic bronchitis	Yes ☐ No ☐ Unknown ☐
	<u>Nose and eye symptoms</u>	
14	Have you ever had any nose or eye problems or allergies such as allergic rhinitis ?	Yes ☐ No ☐
	If YES, go on to Question 14.1 Answer all questions ***If NO, skip to Question 14.4***	
14.1	How old were you when you first noticed these symptoms?	Years old ☐
14.2	During the past 12 months have you had **two or more** episodes of:	
14.2.1	Sneezy, itchy or runny nose when you did not have a cold or flu?	Yes ☐ No ☐
14.2.2	Red, itchy or watery eyes	Yes ☐ No ☐
14.2.3	Do you usually have the nose or eye symptoms at any particular time of the year?	Yes ☐ No ☐

14.2.3.1 If YES, which is the **worst** season?

Give all options at once

Insert a cross (X) next to ONE answer only

a) Winter ☐

b) Summer ☐

If YES to any of question 14.2, go on to Question 14.3

14.3 Do your nose or eye symptoms seem better or worse when you are away from work (for example, on weekends, off-shift and annual leave?)

<u>Give all options at once</u>

Insert a cross (X) next to ONE answer only

a) Stay the same ☐

b) Get better ☐

c) Get worse ☐

14.4 Does being at work ever cause you to have sneezy/ itchy/runny nose or red/itchy/watery eyes? Yes ☐ No ☐

If YES to any one of the above, go on to Question 14.4.1

If NO, skip to Question 14.6

14.4.1 Since when have you been having these symptoms at work? Month ____ Year ____

14.4.2 Is there anything that you work with **(e.g. "fresh"vs "dry"wood, glue, varnish)**or any other substance that causes you to have these symptoms? Yes ☐ No ☐

If YES, go on to Question 14.4.3

If NO, skip to Question 14.5

14.4.3 What do you think is causing these symptoms?

____

14.5 Are you using any medicines, including nose sprays, drops, tablets or injections, for your nose or eye symptoms at present? Yes ☐ No ☐

If YES, go on to Question 14.5.1

If NO, go on to Question 14.6

<u>Present a chart with different allergy medicines</u>

(N.B. a worker might show you his/her medicines).

14.5.1 Which medicines? ____________________

____

14.6 Did you have hay fever (itchy or watery eyes/nose) as a child? Yes ☐ No ☐

C. FAMILY HISTORY

1	Do/did any members of your family (blood relatives) ever have any kind of allergies?	Yes ☐ No ☐ Unknown ☐
	<u>Do not include relatives by marriage</u>	
	If family history is completely unknown (subject is adopted, etc.), mark UNK and do not complete table. Move to next section	
	If YES, complete table below. Insert a cross (X) in the appropriate block for each option	

		No one in family	Yes, present in family			Do not know
			Parent	Brother/sister	Child	
1.1	Allergic rhinitis					
12	Eczema					
1.3	Asthma					
1.4	Other					
	Specific:					

D. SMOKING HISTORY

1	Have you ever smoked tobacco (cigarettes or pipe) for as long as a year?	Yes ☐ No ☐
	'YES' means at least 20 packs of cigarettes or 360 grams of tobacco in a lifetime or at least one cigarette/day for one year	
	If YES, go on to Question 1.1 ***If NO, skip to Question 2***	
1.1	How old were you when you started smoking?	Years old ☐
1.2	Do you now smoke?	Yes ☐ No ☐
	'YES' means smoking tobacco in the last month or more	
	If YES, go on to Question 1.2.1-2 ***If NO, skip to Question 1.3***	
1.2.1-2	How much do you now smoke on average?	
1.2.1	Number of cigarettes per day	☐
1.2.2	Number of convoluted tobacco per day?	☐
1.3	Have you stopped smoking completely?	Yes ☐ No ☐
	If YES, go on to Question 1.3.1 ***If NO, skip to Question 1.4***	
1.3.1	How old were you when you stopped smoking completely?	Years old ☐

1.3.1.1	How many years in total did you smoke cigarettes? (Do not include the years you stopped before you started again)	Years ☐
1.3.2	On average of the entire time you smoked, how much did you smoke?	
1.3.2.1	Number of cigarettes per day	☐
1.3.2.2	Number of convoluted tobacco per day	☐
1.4	Do you or did you inhale the smoke?	Yes ☐ No ☐
2	Have you been regularly exposed to tobacco smoke from other people smoking cigarettes or pipe in the last 12 months?	Yes ☐ No ☐
	'Regularly' means on most days or nights	

F. HEALTH AND SAFETY EDUCATION AND TRAINING

1	What are the hazards associated with wood processing?	
	______________________________	
	______________________________	
	______________________________	
2	Have you had any health and safety training on how to protect yourself when working in wood processing industry?	Yes ☐ No ☐

G. WORK HISTORY IN WOOD PROCESSING INDUSTRY

1 How long have you been working at this company?

Years ☐ Months ☐

Present job

2 How long have you been working in your current job? Years ☐ Months ☐

3.1 In which division are you currently working?

Refer to exposure area list to identify division

- a) Sawing ☐
- b) Machinery ☐
- c) Setting ☐
- d) Planing ☐
- e) Drilling ☐
- f) Varnishing ☐
- g) Painting ☐
- h) Upholstering ☐
- i) Carving ☐
- j) Cleaning ☐
- k) Shop ☐
- l) Transport ☐
- m) Administration ☐
- n) Other ☐

Specify: ____

3.2 What is your job/task in this area?

Job Title ____

Get a short description of the job

____

____

____

3.3 What type of chemicals do you work with?

Answer one or more questions by insering a cross (X)

a) Glues	Yes	☐
	No	☐
b) Dyes	Yes	☐
	No	☐
c) Dryers	Yes	☐
	No	☐
Varnishes	Yes	☐
	No	☐
f) Hardeners	Yes	☐
	No	☐

	g) Other	Yes ☐
		No ☐
	Specify:	
3.4	What types of woods do you work with?	
	Answer one or more questions by insering a cross (X)	
	a) Panga-panga	Yes ☐
		No ☐
	b) Mahogany bean	Yes ☐
		No ☐
	c) African teak	Yes ☐
		No ☐
	d) Lebombo ironwood	Yes ☐
		No ☐
	e) African mahogany	Yes ☐
		No ☐
	f) Pine	Yes ☐
		No ☐
	g) African sandalwood	Yes ☐
		No ☐
	h) Cordyla africana	Yes ☐
		No ☐
	i) Zebrawood	Yes ☐
		No ☐
	j) Missanda	Yes ☐
		No ☐
	g) Other	Yes ☐
		No ☐
	Specify:	
3.5	What origin of wood (National or imported?)	
3.6	Do you ever do other jobs during your shift on a regular basis (almost every day)?	Yes ☐
		No ☐
	If **Yes**, which jobs?	

3.7	How much dust would you say your current job produces:	
	Give all options at once	
	Insert a cross (X) next to ONE a nswer only	
	a) No dust	☐
	b) A little	☐
	c) A medium amount	☐
	d) A lot	☐
3.8	Does your job involve cleaning activities?	Yes ☐
	Give all options at once	No ☐
3.8.1	General cleaning	Yes ☐
		No ☐
3.8.2	Clean equipment	Yes ☐
		No ☐
3.8.3	Clean Personal Protective Equipment	Yes ☐
		No ☐
3.8.4	Other	Yes ☐
		No ☐
	Specify:	
3.9	How far do you work from the source of the dust?	
	Give all options at once	
	Insert a cross (X) next to ONE answer only	
	a) Right next to the source	☐
	b) About 1-2 metres away	☐
	c) More than 3 metres away	☐
	d) Does not apply	☐
3.10.	Do you use any personal protective equipment on a regular basis (almost every day) while doing your job?	Yes ☐
		No ☐
3.10.1	***If NO, skip to Question 4***	
	If YES, continue with Question 3.6.1	
	Which of the following personal protective equipment do you use on a **regular** basis (almost every day)?	
3.10.1.1	Goggles:	Yes ☐
		No ☐
3.10.1.2	Gloves:	Yes ☐
		No ☐
3.10.1.3	Mask:	Yes ☐
		No ☐
3.10.1.4	Aprons:	Yes ☐
		No ☐

3.10.1.5	Other:	Yes ☐
		No ☐
	Specify: ________	
	If NO to all of the previous questions, skip to Question 4 ***If YES to any one of the above questions, continue with Question 3.6.2***	
3.10.2	How long have you been wearing the personal protective equipment on a regular basis (almost every day) while working?	
3.10.2.1	Goggles	Years ☐
3.10.2.2	Gloves:	Years ☐
3.10.2.3	Mask:	Years ☐
3.10.2.4	Aprons:	Years ☐
3.10.2.5	Other:	Years ☐

Previous jobs in present company

4	Before doing this job at this company, did you do a different job here?	Yes ☐
		No ☐
	If NO, skip to question 5 ***If YES, continue with question 4.1***	
4.1	What other jobs did you do here?	
	Start with the first job and work forward, getting a one-line description of each job. If casual worker, denote each period of employment as a separate job. For continuous years of seasonal work consider as one job (provided no broken years service)	

Job 1

4.1.1	Area/section	________
4.1.2	Job Title	________
	Get a short description of the job	
	________	
	________	
	________	
	________	
4.1.3	Permanent/casual:	________
4.1.4	How long did you work in this job?	Years ☐
		Months ☐

4.1.5	In which area were you working?	
	a) Sawing	☐
	b) Machinery	☐
	c) Setting	☐
	d) Planing	☐
	e) Drilling	☐
	f) Varnishing	☐
	g)Painting	☐
	h) Upholstering	☐
	i) Carving	☐
	j) Cleaning	☐
	k) Shop	☐
	l) Transport	☐
	m) Administration	☐
	n) Other	☐
	Specify:	

4.1.6	What types of wood did you work with?		
	Answer one or more questions by inserting a cross (X)		
	a) Panga-panga	Yes	☐
		No	☐
	b) Mahogany bean	Yes	☐
		No	☐
	c) African teak	Yes	☐
		No	☐
	d) Lebombo ironwood	Yes	☐
		No	☐
	e) African mahogany	Yes	☐
		No	☐
	f) Pine	Yes	☐
		No	☐
	g) African sandalwood	Yes	☐
		No	☐
	h) Cordyla africana	Yes	☐
		No	☐
	i) Zebrawood	Yes	☐
		No	☐
	j) Missanda	Yes	☐
		No	☐
	g) Other	Yes	☐
		No	☐
	Specify:		

4.1.7	How much dust would you say your current job produces:		
	Give all options at once ***Insert a cross (X) next to ONE a nswer only***		
	a) No dust		☐
	b) A little		☐
	c) A medium amount		☐
	d) A lot		☐
4.1.8	Does your job involve cleaning activities?		
	Give all options at once ***If YES, continue with 4.1.8 (one or more), If NO go to 4.1.9***		
4.1.8.1	General cleaning	Yes	☐
		No	☐
4.1.8.3	Clean equipment	Yes	☐
		No	☐
4.1.8.4	Clean PPE	Yes	☐
		No	☐
4.1.8.8	Other	Yes	☐
		No	☐
	Specify:		
4.1.9	How far did you work from the source of the dust?		
	Give all options at once ***Insert a cross (X) next to ONE answer only***		
	a) Right next to the source		☐
	b) About 1-2 metres away		☐
	c) More than 3 metres away		☐
	d) Does not apply		☐
4.1.10	Did you use any personal protective equipment	Yes	☐
	on a regular basis (almost every day) while doing your	No	☐
	job?		
	If NO, skip to Question 4.2.1 ***If YES, continue with Question 4.1.10***		
4.1.10.1-5	Which of the following personal protective		
	equipment did you use on a regular basis (almost every		
	day)?		
4.1.10.1	Goggles:	Yes	☐
		No	☐
4.1.10.2	Gloves:	Yes	☐
		No	☐
4.1.10.3	Mask:	Yes	☐
		No	☐
4.1.10.4	Aprons:	Yes	☐
		No	☐

4.1.10.5	Other:	Yes [ ]
	If NO to all of the previous questions, skip to Question 4.2.1	No [ ]
	If YES to any one of the above questions, continue with Question 4.1.11	
4.1.11	How long have you been wearing the personal protective equipment on a regular basis (almost every day) while working?	
4.1.11.1	Goggles	Years [ ]
4.1.11.2	Gloves:	Years [ ]
4.1.11.3	Mask:	Years [ ]
4.1.11.4	Aprons:	Years [ ]
4.1.11.5	Other:	Years [ ]

<u>Job 2</u>

4.2.1	Area/section	
4.2.2	Job Title	
	Get a short description of the job	
4.2.3	Permanent/casual:	
4.2.4	How long did you work in this job?	Years [ ]
		Months [ ]
4.2.5	In which area were you working?	
	a) Sawing	[ ]
	b) Machinery	[ ]
	c) Setting	[ ]
	d) Planing	[ ]
	e) Drilling	[ ]
	f) Varnishing	[ ]
	g)Painting	[ ]
	h) Upholstering	[ ]
	i) Carving	[ ]
	j) Cleaning	[ ]
	k) Shop	[ ]
	l) Transport	[ ]
	m) Administration	[ ]
	n) Other	[ ]
	Specify:	

4.2.6 What types of wood did you work with?

Answer one or more questions by inserting a cross (X)

a) Panga-panga	Yes		
	No		
b) Mahogany bean	Yes		
	No		
c) African teak	Yes		
	No		
d) Lebombo ironwood	Yes		
	No		
e) African mahogany	Yes		
	No		
f) Pine	Yes		
	No		
g) African sandalwood	Yes		
	No		
h) Cordyla africana	Yes		
	No		
i) Zebrawood	Yes		
	No		
j) Missanda	Yes		
	No		
g) Other	Yes		
	No		
Specify:			

4.2.7 How much dust would you say your current job produces:

Give all options at once

Insert a cross (X) next to ONE a nswer only

a) No dust	
b) A little	
c) A medium amount	
d) A lot	

4.2.8 Does your job involve cleaning activities?

Give all options at once

If YES, continue with 4.1.8 (one or more), If NO go to 4.1.9

4.2.8.1 General cleaning	Yes	
	No	
4.2.8.2 Clean equipment	Yes	
	No	

4.2.8.3	Clean Personal Protective Equipment	Yes
		No
4.2.8.4	Other	Yes
		No
	Specify:	

4.2.9 How far did you work from the source of the dust?

Give all options at once

Insert a cross (X) next to ONE answer only

a) Right next to the source

b) About 1-2 metres away

c) More than 3 metres away

d) Does not apply

4.2.10	Did you use any personal protective equipment on a regular basis (almost every day) while doing your job?	Yes
		No

If NO, skip to Question 4.3.1

If YES, continue with Question 4.2.10

4.2.10.1-5 Which of the following personal protective equipment did you use on a regular basis (almost every day)?

4.2.10.1	Goggles:	Yes
		No
4.2.10.2	Gloves:	Yes
		No
4.2.10.3	Mask:	Yes
		No
4.2.10.4	Aprons:	Yes
		No
4.2.10.5	Other:	Yes
		No

If NO to all of the previous questions, skip to Question 4.3.1

If YES to any one of the above questions, continue with Question 4.2.11

4.2.11 How long have you been wearing the personal protective equipment on a regular basis (almost every day) while working?

4.2.11.1	Goggles	Years
4.2.11.2	Gloves:	Years
4.2.11.3	Mask:	Years
4.2.11.4	Aprons:	Years
4.2.11.5	Other:	Years

Job 3

4.3.1	Area/section	
4.3.2	Job Title	
	Get a short description of the job	
4.3.3	Permanent/casual:	
4.3.4	How long did you work in this job?	Years
		Months
4.3.5	In which area were you working?	
	a) Sawing	
	b) Machinery	
	c) Setting	
	d) Planing	
	e) Drilling	
	f) Varnishing	
	g)Painting	
	h) Upholstering	
	i) Carving	
	j) Cleaning	
	k) Shop	
	l) Transport	
	m) Administration	
	n) Other	
	Specify:	
4.3.6	What types of wood did you work with?	
	Answer one or more questions by inserting a cross (X)	
	a) Panga-panga	Yes
		No
	b) Mahogany bean	Yes
		No
	c) African teak	Yes
		No
	d) Lebombo ironwood	Yes
		No
	e) African mahogany	Yes
		No
	f) Pine	Yes
		No

h) Cordyla africana — Yes ☐ No ☐

i) Zebrawood — Yes ☐ No ☐

j) Missanda — Yes ☐ No ☐

4.3.7 How much dust would you say that this job produced:

Give all options at once
Insert a cross (X) next to ONE answer only

a) No dust ☐
b) A little ☐
c) A medium amount ☐
d) A lot ☐

4.3.8 Does your job involve cleaning activities? — Yes ☐ No ☐

Give all options at once
If YES, continue with 4.3.8 (one or more), If NO go to 4.3.9

4.3.8.1 General cleaning — Yes ☐ No ☐

4.3.8.2 Clean equipment — Yes ☐ No ☐

4.3.8.3 Clean PPE — Yes ☐ No ☐

4.3.8.4 Other — Yes ☐ No ☐

Specify: ____________________

4.3.9 How far did you work from the source of the dust?

Give all options at once
Insert a cross (X) next to ONE an swer only

a) Right next to the source ☐
b) About 1-2 metres away ☐
c) More than 3 metres away ☐
d) Does not apply ☐

4.3.10 Did you use any personal protective equipment on a regular basis (almost every day) while doing your job? — Yes ☐ No ☐

If NO, skip to Question 4.4.1

If YES, continue with Question 4.3.10

4.3.10.1-5	Which of the following personal protective equipment did you use on a regular basis (almost every day)?	
4.3.10.1	Goggles:	Yes ☐ No ☐
4.3.10.2	Gloves:	Yes ☐ No ☐
4.3.10.3	Mask:	Yes ☐ No ☐
4.3.10.4	Aprons:	Yes ☐ No ☐
4.3.10.5	Other:	Yes ☐ No ☐
	If NO to all of the previous questions, skip to Question 4.4.1 ***If YES to any one of the above questions, continue with Question 4.3.11***	
4.3.11	How long have you been wearing the personal protective equipment on a regular basis (almost every day) while working?	
4.3.11.1	Goggles	Years ☐
4.3.11.2	Gloves:	Years ☐
4.3.11.3	Mask:	Years ☐
4.3.11.4	Aprons:	Years ☐
4.3.11.5	Other:	Years ☐

Previous work experience

5 Name all the previous workplaces that you have worked in, when not working in this company or before coming to work in this company:

Start with the most recent job and work backwards (including all other companies and jobs done)

Name of Company	What did the company make?	Job title (what did you do?)	Date started (year)	Date ended (year)	Total years

THANK YOU FOR ANSWERING THE QUESTIONNAIRE

Interviewer's name: ____________________

Date of interview: Day ______ Month ______ Year ______

UCT/UEM ASMA RELACIONADA AO TRABALHO ENTRE OS TRABALHADORES DA INDUSTRIA DE PROCESSAMENTO DE MADEIRA EM MOÇAMBIQUE - 2017

QUESTIONÁRIO

Nota: Responda a TODAS as questoes. Insira uma cruz (X) onde for apropriado

Numero do Estudo

Empregador/Nome da empresa:

Sitio ou localização:

Província

A. DADOS DE IDENTIFICAÇÃO

1	Apelido					
3	Primeiro nome/s					
3	Endereço					
4	Número do trabalhador					
5	Data de nascimento:	Dia		Mês	Ano	
6	Gênero :				Masculino	
					Feminino	
7	Língua materna:				Português	
					Ronga	
					Changana	
					Sena	
					Ndau	
					Outra	
8	Você é trabalhador eventual ou efectivo?				Eventual	
					Efectivo	
9	Regime de trabalho				Dia	
					Noite	
10	Horário de trabalho/turno					
11	Último dia de trabalho?	Dia		Mês	Ano	

B. PROBLEMAS DE SAÚDE

Chiado e aperto no peito

1	Você já teve Chiado ou assobio no peito no passado?	Sim
		Não
	se SIM, vai para a Pergunta 1.1	
	se NÃO, salte para a Pergunta 2	
1.1	Se sim, quando foi a primeira vez que você teve esses sintomas? Mês	Ano
1.2	Já teve chiado ou assobio no seu peito	Sim
	alguma vez nos **últimos 12 meses?**	Não
	se SIM, vai para a Pergunta 1.2.1	
	se NÃO, salte para a Pergunta 3	
1.2.1	Esteve com falta de ar quando chiava?	Sim
		Não
1.2.2	Teve esse Chiado ou assobio quando	Sim
	não tinha resfriado ou gripe?	Não
2	Alguma vez acordou com a sensação	Sim
	de aperto no peito nos **últimos 12 meses?**	Não

Falta de ar

3	Alguma vez teve ataque de falta de ar durante	Sim
	o dia em repouso nos **últimos 12 meses?**	Não
4	Em algum momento teve ataque de falta de ar	Sim
	a seguir à corrida ou exercício físico nos **últimos 12 meses?**	Não
5	Alguma vez acordou devido ao ataque de falta de ar	Sim
	nos **últimos 12 meses?**	Não

Tosse e catarro do peito

6	Alguma vez acordou devido ao ataque de tosse nos	Sim
	nos **últimos 12 meses?**	Não
7	Geralmente tosse de manhã muito cedo?	Sim
		Não
8	Geralmente tosse durante o resto do dia, ou	Sim
	à noite?	Não
	se SIM, vai para a Pergunta 8.1	
	se NÃO, salte para a Pergunta 9	
8.1	Tem tossido desta maneira na maior parte dos dias/noites	Sim
	durante três meses ou mais nos últimos dois anos?	Não
9	Geralmente tira expectoração do seu peito de manhã muito cedo?	Sim

10	Geralmente tira expectoração do seu peito durante o dia, ou à noite	Sim
		Não
	se SIM, vai para a Pergunta 10.1	
	se N ÃO, salte para a Pergunta 11	
10.1	Tem tirado expectoração desta maneira na maior parte dos dias/noi	Sim
	durante três meses ou mais nos últimos dois anos?	Não
	Respiração	
11	Alguma vez teve problemas de respiração?	Sim
	se SIM, vai para a Pergunta 11.1	Não
	se N ÃO, salte para a Pergunta 12	
11.1	Você tem este problema:	
	Dar todas as opções de uma só vez	
	Inserir uma cruz (X) ao lado de uma resposta somente	
	a) continuamente de tal modo que a sua respiração nunca està bem?	
	b) repetidamente, mas desaparece completamente entre os períodos de	
	tempo em que este problema o perturba?	
	c) Só raramente?	
12	Você está incapacitado de andar por uma outra condição	Sim
	que não doença pulmonar ou cardíaca?	Não
	se SIM, indicar a condi ção	
	e vai para a Pergunta 13	
	se N ÃO, vai para a Pergunta 12.1	
12.1	Tem tido problemas de falta de ar quando caminha depressa	Sim
	em terreno plano ou quando faz uma pequena subida?	Não
	se SIM, vai para a Pergunta 12.1.1	
	se N ÃO, salte para a Pergunta 13	
12.1.1	Tem sentido falta de ar quando anda com outras pessoas	Sim
	da sua idade em terreno plano?	Não
12.1.2	Tem tido de parar para respirar quando anda no seu próprio ritmo,	Sim
	em terreno plano?	Não
	Asma	
13	Alguma vez você já teve asma?	Sim
		Não
	se SIM, vai para a Pergunta 13.1	
	se N ÃO, salte para a pergunta 13.8	
13.1	Se sim, foi ela confirmada pelo médico?	Sim
		Não

13.2 Que idade você tinha quando lhe disseram que tinha asma?

Dar todas as opções de uma só vez

Inserir uma cruz (X) ao lado de uma resposta somente

a) Antes dos 17 anos de idade ☐

b) Aos 17 anos de idade ou mais ☐

c) Ambos ☐

As seguintes referências de "ataque" de asma refere-se a episódios de chiado no peito, falta de ar, aperto no peito ou tosse atribuidos a asma.

13.3.1 Que idade tinha quando teve o seu primeiro ataque de asma? idade ☐

13.3.2 Que idade tinha quando teve o seu mais recente ataque de asma? idade ☐

13.4 Em que meses do ano geralmente tem ataques de asma?

Responder a todas as perguntas, inserir uma cruz (X)

13.4.1	Janeiro/Fevereiro	Sim ☐	Não ☐
13.4.2	Março/Abril	Sim ☐	Não ☐
13.4.3	Maio/Junho	Sim ☐	Não ☐
13.4.4	Julho/Agosto	Sim ☐	Não ☐
13.4.5	Setembro/Outubro	Sim ☐	Não ☐
13.4.6	Novembro/Dezembro	Sim ☐	Não ☐

13.5 Teve algum ataque de asma nos últimos **12 meses?** Sim ☐ Não ☐

se SIM, vai para a Pergunta 13.5.1

se N ÃO, salte para a Pergunta 13.6

13.5.1 Com que frequência tem tido ataques de asma nos últimos 12 meses?

Dar todas as opções de uma só vez

Inserir uma cruz (X) ao lado de uma resposta somente

a) Todos os dias ☐

b) Mais de 2 vezes por semana ☐

c) Mais de 1 vez por mês ☐

d) 3 a 12 vezes em todo o ano ☐

e) 1 a 2 vezes em todo o ano ☐

13.6	São os sintomas do peito causados por, ou agravados por qualquer um dos seguintes:	
	Responder a todas as perguntas, insira uma cruz (X)	
13.6.1	Contacto com animais/ animais de estimação	Sim ☐ Não ☐
13.6.2	Relva ou flores	Sim ☐ Não ☐
13.6.3	Exercícios pesados	Sim ☐ Não ☐
13.6.4	Respiração de ar frio	Sim ☐ Não ☐
13.6.5	Poeiras ou sprays no trabalho	Sim ☐ Não ☐
13.6.6	Fumo de tabaco	Sim ☐ Não ☐
13.6.7	Mudanças de tempo	Sim ☐ Não ☐
13.7	Os seus sintomas torácicos parecem melhores ou piores quando estás fora do trabalho (por exemplo, nos finais de semana, fora de turno, licença anual)?	
	<u>Dar todas as opções de uma só vez</u> ***Inserir uma cruz (X) ao lado de uma resposta somente***	
	a) Mantêm-se na mesma	☐
	b) Melhoram	☐
	c) Pioram	☐
13.8	O estar no trabalho faz lhe sentir aperto no peito ou dificuldade respiratória?	Sim ☐ Não ☐
	se SIM, vai para pergunta 13.8.1 ***se N ÃO, salte para a pergunta 13.9***	
13.8.1	Quando é que pela primeira vez notou ter problemas de aperto no peito ou dificuldade respiratória no trabalho? Mês ____	Ano ____
13.82	Há alguma coisa com que trabalha **(actividades específicas na empresa de processamento de madeira)** que causa em si esses sintomas torácicos?	Sim ☐ Não ☐
	se SIM, vai para a pergunta 13.8.3 ***se N ÃO, salte para a pergunta 13.9***	
13.8.3	O que você acha que está causando estes sintomas?	
	____	

13.9 Alguma vez teve que mudar ou deixar o seu local de trabalho, temporariamente ou permanentemente, nesta empresa ou em alguma outra por causa de quaisquer sintomas do peito? Sim ☐ Não ☐

se SIM, vai para a pergunta 13.9.1
se N ÃO, salte para a pergunta 13.10

13.9.1 Que tipo de trabalho estava fazendo quando isso aconteceu?

13.9.2 Era este o trabalho que fazia nesta empresa? Sim ☐ Não ☐

se SIM, vai para a pergunta 13.9.2.1
se N ÃO, salte para a pergunta 13.10

13.9.2.1 Para que área/secção mudou?

13.9.2.2 Que trabalho lá fazia?

13.9.2.3 Os seus sintomas melhoraram quando mudou de trabalho? Sim ☐ Não ☐

13.10 Já trabalhou em ocupação ou ocupações que o exposessem á outras substâncias além da poeira da madeira **(por exemplo, alimentos de animais , lixo, roupa de cama, penas)** ou fumos? Sim ☐ Não ☐

se SIM, vai para a pergunta 13.10.1.
Listar os trabalhos começando com o mais recente
se N ÃO, salte para a pergunta 13.11

13.10.1 Qual foi ou é esta ocupação?

(Se ocupação corrente, escreva "ocupação corrente" e especifique)

13.10.2 Antes disso?

13.11 Já houve algum momento em que inalou uma grande quantidade de vapor, gás ou fumos em qualquer uma dessas ocupações que Resultou no desenvolvimento de aperto no peito, chiado ou tosse Sim ☐ Nao ☐

se SIM, vai para a pergunta 13.11.1.
se N ÃO, salte para a pergunta 13.12

13.11.1 Qual foi ou é esta ocupação?

(se for ocupação corrente, escreva "ocupação corrente" e especifique)

13.12	Você está usando algum medicamento, incluindo bombas/ inaladores, nebulizadores, xaropes ou comprimidos, para asma ou problemas respiratórios?	Sim ☐ Não ☐
	se SIM, vai para a pergunta 13.12.1, apresentando exemplos de cada um ***se NÃO, salte para a pergunta 13.13***	
13.12.1	Que medicamentos?	
13.12.2	Você toma estes medicamentos todos os dias mesmo quando não tem qualquer dificuldade respiratória?	Sim ☐ Não ☐
13.13	Já foi tratado a qualquer um dos seguintes problemas:	
	Responder a todas as perguntas	
13.13.1	Infecções do peito repetidas quando criança	Sim ☐ Não ☐ Desconhecido ☐
13.13.2	Tuberculose (TB)	Sim ☐ Não ☐ Desconhecido ☐
13.13.3	Bronquite crónica	Sim ☐ Não ☐ Desconhecido ☐
	Sintomas oculares ou nasais	
14	Já teve problemas oculares ou nasais ou alergias tais como renite alérgica ?	Sim ☐ Não ☐
	se SIM, vai para a pergunta 14.1 Responda a todas as perguntas ***se N ÃO, salte para a pergunta 14.4***	
14.1	Que idade tinhas quando pela primeira vez notou estes sintomas?	Idade ☐
14.2	Durante os últimos 12 meses teve **dois ou mais** episódios de:	
14.2.1	Espirros, comichão ou corrimento nasal quando não tinha resfriado ou gripe?	Sim ☐ Não ☐
14.2.2	Olhos avermelhados, irritados ou lacrimejantes	Sim ☐ Não ☐
14.2.3	Geralmente tem sintomas nasais ou oculares em algum momento específico do ano?	Sim ☐ Não ☐

14.2.3.1	se SIM, qual é **a pior** estação?	
	<u>Dar todas as opções de uma só vez</u>	
	Inserir uma cruz (X) ao lado de uma resposta somente	
	a) Inverno	☐
	b) Verão	☐
	se respondeu SIM a qualquer das perguntas 14.2, vai para a pergunta 14.3	
	se N ÃO, salte para a pergunta 14.4	
14.3	Os seus sintomas nasais e oculares parecem melhorar ou piorar quando está fora do serviço (por exemplo, nos finais de semana fora de turno e licença anual?)	
	<u>Dar todas as op ções de uma só vez</u>	
	Inserir uma cruz (X) ao lado de uma resposta somente	
	a) Mantêm-se na mesma	☐
	b) Melhoram	☐
	c) Pioram	☐
14.4	O estar no serviço alguma vez provocou-lhe ter espirros/comichão/ corrimento nasal ou ter olhos avermelhados, irritados ou lacrimejar	Sim ☐ Não ☐
	se SIM a alguma das quest ões acima, v á para a pergunta 14.4.1	
	se N ÃO, salte para a pergunta 14.6	
14.4.1	Desde quando você tem tido esses sintomas no serviço? Mês ___	Ano ___
14.4.2	Alguma coisa com que trabalha **(por exemplo, madeira "fresca"vs "seca", cola, veniz)** ou alguma outra substância faz com que tenha estes sintomas?	Sim ☐ Não ☐
	se SIM, vai para a pergunta 14.4.3	
	se N ÃO, salte para a pergunta 14.5	
14.4.3	O que acha que causa esses sintomas?	
	___	
14.5	Está usando algum medicamento, incluindo sprays nasais, gotas, comprimidos ou injecções, para os seus sintomas nasais ou oculares no presente?	Sim ☐ Não ☐
	se SIM, vai para a pergunta 14.5.1	
	se N ÃO, vai para a pergunta 14.6	
	<u>Apresentar um gráfico com diferentes medicamentos de alergia</u>	
	(N.B. o trabalhador(a) poderá mostrar os medicamentos) .	
14.5.1	Que medicamentos? ___	
	___	
14.6	Teve febre de feno (irritação nasal ou ocular e olhos lacrimejantes) quando criança?	Sim ☐ Não ☐

C. HISTÓRIA FAMILIAR

1 Algum membro da sua família tem/teve (parentes sanguíneos) algum tipo de alergia? Sim / Não / Desconhecido

<u>Não inclua parentes por casamento</u>

se a história é completamente desconhecida (o indivíduo é adoptado, etc.) marque desconhecido e não complete a tabela. Passe para a secção seguinte

se SIM, complete a tabela abaixo. Inserir uma cruz (X) no bloco apropriado para cada opção

		Ninguém na família	Sim, presente na família			Não sei
			Pai/ mãe	Irmão/irmã	Filho	
1.1	Renite alérgica					
1.2	Eczema					
1.3	Asma					
1.4	Outras					
	Especifique:					

D. HISTÓRIA DE TABAGISMO

1 Já alguma vez fumou tabaco (cigarros ou cachimbo) por mais de um ano? Sim / Não

'SIM' significa que pelo menos 20 maços de cigarros ou 360 gramas de tabaco em sua vida ou pelo menos um cigarro por dia durante um ano

se SIM, vai para a pergunta 1.1
se N ÃO, salte para a pergunta 2

1.1 Que idade tinha quando começou a fumar? Idade

1.2 Você agora fuma? Sim / Não

'SIM' significa fumar tabaco no último mês ou mais

se SIM, vai para a pergunta 1.2.1-2
se N ÃO, salte para a pergunta 1.3

1.2.1-2 Quanto actualmente fuma em média?

1.2.1 Número de cigarros por dia

1.2.2 Número de folhas de tabaco enrolado por dia?

1.3 Já parou completamente de fumar? Sim / Não

se SIM, vaipara a pergunta 1.3.1
se N ÃO, salte para a pergunta 1.4

1.3.1 Que idade tinha quando parou completamente de fumar? Idade

1.3.1.1	Quantos anos no total você fumou cigarros?	Anos ☐
	(Não inclua os anos que você parou de fumar)	
1.3.2	Em todo o tempo que fumou, quanto em média fumou?	________________
1.3.2.1	Número de cigarros por dia	☐
1.3.2.2	Número de folhas de tabaco enrolado por dia	☐
1.4	Você inala ou inalou fumo?	Sim ☐
		Não ☐
2	Tem sido exposto regularmente ao fumo de tabaco por outras	Sim ☐
	pessoas que fumam cigarros ou tabaco nos últimos	Não ☐
	12 meses?	
	'Regularmente' significa na maior parte dos dias ou noites	

F. TREINAMENTO E EDUCAÇÃO EM SAÚDE E SEGURANÇA

1	Que riscos estão associados ao processamento de madeira?	
	____	
	____	
	____	
2	Já teve algum treinamento em saúde e segurança sobre como se	Sim ☐
	proteger quando estiver trabalhando na indústria de processament	Não ☐
	de madeira?	

G. HISTÓRIA DE TRABALHO NA INDÚSTRIA DE PROCESSAMENTO DE MADEIRA

1 Há quanto tempo trabalha nesta empresa?

Anos ___ Meses ___

Ocupação actual

2 Há quanto tempo trabalha no emprego actual?

Anos ___ Meses ___

3.1 Em que secção trabalha actualmente?

Consulte a lista de área de exposição para identificar a secção

a) Serração
b) Maquinaria
c) Montagem
d) Aplainação
e) Perfuração
f) Envernizamento
g) Pintura
h) Estofagem
i) Escultura
j) Limpeza
k) Loja
l) Transporte
m) administração
n) Outros

Especificar: ___

3.2 Qual é o seu trabalho/tarefa nesta área?

Título do trabalho ___

Dar uma breve descrição do trabalho

___

___

___

3.3 Com que tipos de quimicos trabalha?

Responder a uma ou mais perguntas, inserindo uma cruz (X)

a) Cola	Sim	
	Não	
b) Corantes	Sim	
	Não	
c)Solventes	Sim	
	Não	
d) Verniz	Sim	
	Não	
e) Endurecedor	Sim	
	Não	

	g) Outros	Sim
		Não
	Especificar: Por exemplo, Pestecidas	
3.4	Com que tipos de madeira trabalha?	
	Responder a uma ou mais perguntas, inserindo uma cruz (X)	
	a) Jambire	Sim
		Não
	b) Chanfuta	Sim
		Não
	c) Umbila	Sim
		Não
	d) Mecrusse	Sim
		Não
	e) Umbaua	Sim
		Não
	f) Pinho	Sim
		Não
	g) Sândalo africano	Sim
		Não
	h) Cordila africana	Sim
		Não
	i) Zebra	Sim
		Não
	j) Missanda	Sim
		Não
	g) Outras	Sim
		Não
	Especificar:	
3.5	Qual é a origem da madeira (Nacional ou importado)? ______________________________	
3.6	Você faz regularmente (quase todos os dias) outros trabalhos	Sim
	durante o seu turno?	Não
	Se **Sim**, que trabalhos?	

3.7	Quanta poeira você diria que a sua ocupação actual produz:	
	Dar todas as opções de uma só vez	
	Inserir uma cruz (X) ao lado de uma resposta somente	
	a) Sem poeira	
	b) Pouca	
	c) Uma quantidade média	
	d) Muita	
3.8	O seu trabalho envolve actividades de limpeza?	Sim
		Não
	Dar as opções de uma só vez	
	se SIM, continue com 3.8.1 (uma ou mais), se N ÃO vai para 3.9	
3.8.1	Limpeza geral	Sim
		Não
3.8.2	Limpeza dos equipamentos	Sim
		Não
3.8.3	Limpeza do Equipamento de Protecção Individual	Sim
		Não
3.8.4	Outros	Sim
		Não
	Especificar:	
3.9	Quão longe você trabalha da fonte da poeira?	
	Dar todas as opções de uma só vez	
	Inserir uma cruz (X) ao lado de UMA resposta somente	
	a) Ao lado da fonte	
	b) Aproximadamente 1-2 metros	
	c) Mais de 3 metros de distância	
	d) Não se aplica	
3.10	Usa regularmente (quase todos os dias) algum equipamento de	Sim
	protecção individual enquanto faz o seu trabalho?	Não
	se N ÃO, salte para a pergunta 4	
	se SIM, continue com a pergunta 3.10.1	
3.10.1	Qual dos seguintes equipamentos de protecção individual	
	usa **regularmente** (quase todos os dias?)	
3.10.1.1	Óculos de protecção	Sim
		Não
3.10.1.2	Luvas	Sim
		Não
3.10.1.3	Máscara:	Sim
		Não
3.10.1.4	Aventais	Sim
		Não

3.10.1.5 Outros: Sim ☐ Não ☐

Especificar:

se N ÃO a todas as perguntas anteriores, salte para a pergunta 4
se SIM a alguma das perguntas acima, continue com a Pergunta 3.10.2

3.10.2 Há quanto tempo vem usando regularmente (quase todos os dias) equipamento de protecção individual enquanto trabalha?

3.10.2.1 Óculos de protecção — Anos ☐

3.10.2.2 Luvas: — Anos ☐

3.10.2.3 Máscara: — Anos ☐

3.10.2.4 Aventais: — Anos ☐

3.10.2.5 Outros: — Anos ☐

<u>Ocupações anteriores na presente empresa</u>

4 Antes de fazer este trabalho nesta empresa, você fez algum outro trabalho diferente ? Sim ☐ Não ☐

se N ÃO, salte para a pergunta 5
se SIM, continue com a pergunta 4.1

4.1 Que outros trabalhos você fez aqui?

Começe *com o <u>primeiro trabalho em diante</u>, dando descrição da linha de cada ocupação. Se trabalhador eventual, indicar <u>cada período</u> de trabalho como uma colocação <u>separada</u>. Para nos contínuos de trabalho sazonal considere como uma única ocupação (prestados sem interrupção de tempo de servi ço)*

<u>Ocupação 1</u>

4.1.1 Área/secção

4.1.2 Título da ocupação

***Dar uma breve* descrição do trabalho**

4.1.3 Permanente/eventual:

4.1.4 Quanto tempo trabalhou nesta ocupação? Anos ☐ Meses ☐

4.1.6	Em que área trabalhou?	
	a) Serração	
	b) Maquinaria	
	c) Montagem	
	d) Aplainação	
	e) Prefuração	
	f) Envernizamento	
	g) Pintura	
	h) Estofamento	
	i) Escultura	
	j) Limpeza	
	k) Loja	
	l) Transporte	
	m) Adninistração	
	n) Outra	
	Especificar	

4.1.6	Com que tipos de madeira trabalhou?		
	Responder a uma ou mais perguntas, inserindo uma cruz (X)		
	a) Jambire	Sim	
		Não	
	b) Chanfuta	Sim	
		Não	
	c) Umbila	Sim	
		Não	
	d) Mecrusse	Sim	
		Não	
	e) Umbaua	Sim	
		Não	
	f) Pinho	Sim	
		Não	
	g) Sândalo africano	Sim	
		Não	
	h) Cordila africana	Sim	
		Não	
	i) Zebra	Sim	
		Não	
	j) Missanda	Sim	
		Não	
	k) Outros	Sim	
		Não	
	Especificar		

4.1.7	Quanta poeira você diria que esta ocupação produzia:	
	Dar todas as opções de uma só vez	
	Inserir uma cruz (X) ao lado de uma resposta somente	
	a) Sem poeira	☐
	b) Pouca	☐
	c) Uma quantidade média	☐
	d) Muita	☐
4.1.8	O seu trabalho envolve actividades de limpeza?	
	Dar todas as opções de uma só vez	
	se SIM, continue com 4.1.8 (um ou mais), se N ÃO vai para 4.1.9	
4.1.8.1	Limpeza geral	Sim ☐
		Não ☐
4.1.8.3	Limpeza dos equipamentos	Sim ☐
		Não ☐
4.1.8.4	Limpeza do equipamento de protecção individual	Sim ☐
		Não ☐
4.1.8.8	Outros	Sim ☐
		Não ☐
	Especificar:	
4.1.9	Quão longe trabalhava da fonte da poeira?	
	Dar todas as opções de uma só vez	
	Inserir uma cruz (X) ao lado dê UMA resposta somente	
	a) Ao lado da fonte	☐
	b) Aproximadamente 1-2 metros	☐
	c) Mais de 3 metros de distância	☐
	d) Não se aplica	☐
4.1.10	Usa regularmente (quase todos os dias) algum equipamento de	Sim ☐
	protecção individual enquanto fazia o seu trabalho?	Não ☐
	se NÃO, salte para a pergunta 4.2.1	
	se SIM, continue com a pergunta 4.1.10	
4.1.10.1-5	Qual dos seguintes equipamentos de protecção individual	
	usava regularmente (quase todos os dias?)	
4.1.10.1	Óculos de protecção:	Sim ☐
		Não ☐
4.1.10.2	Luvas:	Sim ☐
		Não ☐
4.1.10.3	Máscara:	Sim ☐
		Não ☐
4.1.10.4	Aventais:	Sim ☐
		Não ☐

4.1.10.5	Outros:	Sim	
	se NÃO a todas as perguntas anteriores, salte para a pergunta 4.2.1	Não	
	se SIM a alguma das perguntas acima, continue com a		
	Pergunta 4.1.11		
4.1.11	Quanto tempo usou regulamente (quase todos os dias) equipamento de protecção individual enquanto trabalhava?		
4.1.11.1	Óculos de protecção	Anos	
4.1.11.2	Luvas:	Anos	
4.1.11.3	Máscara:	Anos	
4.1.11.4	Aventais:	Anos	
4.1.11.5	Outros:	Anos	

Ocupação 2

4.2.1	Área/secção		
4.2.2	Título da ocupação		
	Dar uma breve descrição do trabalho		
4.2.3	Permanente/eventual:		
4.2.4	Quanto tempo trabalhou nesta ocupação?	Anos	
		Meses	
4.2.5	Em que área trabalhou?		
	a) Serração		
	b) Maquinaria		
	c) Montagem		
	d) Aplainação		
	e) Perfuração		
	f) Envernizame		
	g) Pintura		
	h) Esfofaria		
	i) Gravura		
	j) Limpeza		
	k) Loja		
	l) Transporte		
	m) Administração		
	n) Outros		
	Especificar:		

4.2.6	Com que tipos de madeira trabalhou?	
	Responder a uma ou mais perguntas, inserindo uma cruz (X)	
	a) Jambire	Sim
		Não
	b) Chanfuta	Sim
		Não
	c) Umbila	Sim
		Não
	d) Mecrusse	Sim
		Não
	e) Umbaua	Sim
		Não
	f) Pinho	Sim
		Não
	g) Sândalo africano	Sim
		Não
	h) Cordila africana	Sim
		Não
	i) Zebra	Sim
		Não
	j) Missanda	Sim
		Não
	k) Outros	Sim
		Não
	Especificar:	
4.2.7	Quanta poeira você diria que esta ocupação produzia:	
	Dar todas as opções de uma só vez	
	Inserir uma cruz (X) ao lado de uma resposta somente	
	a) Sem poeira	
	b) Pouca	
	c) Uma quantidade média	
	d) Muita	
4.2.8	O seu trabalho envolvia actividades de limpeza?	
	Dar todas as opçõesde uma só vez	
	se SIM, continue com 4.1.8 (um ou mais), se NÃO vai para 4.1.9	
4.2.8.1	Limpeza geral	Sim
		Não
4.2.8.2	Limpeza dos equipamentos	Sim
		Não

4.2.8.3	Limpeza do equipamento de protecção individual	Sim ☐
		Não ☐
4.2.8.4	Outro	Sim ☐
		Não ☐
	Especificar:	
4.2.9	Quão longe trabalhava da fonte da poeira?	
	<u>Dar todas as opções de uma só vez</u>	
	Inserir uma cruz (X) ao lado de uma resposta somente	☐
	a) Ao lado da fonte	☐
	b) Aproximadamente 1-2 metros	☐
	c) Mais de 3 metros de distância	☐
	d) Não se aplica	
4.2.10	Usava regularmente (quase todos os dias) algum equipamento de protecção individual enquanto fazia o seu trabalho?	Sim ☐ Não ☐
	se N ÃO, salte para a pergunta 4.3.1	
	se SIM, continue com a pergunta 4.2.10	
4.2.10.1-5	Qual dos seguintes equipamentos de protecção individual usava regularmente (quase todos os dias?)	
4.2.10.1	Óculos de proteção:	Sim ☐
		Não ☐
4.2.10.2	Luvas:	Sim ☐
		Não ☐
4.2.10.3	Máscara:	Sim ☐
		Não ☐
4.2.10.4	Aventais:	Sim ☐
		Não ☐
4.2.10.5	Outros	Sim ☐
	se NÃO a todas as perguntas anteriores, salte para a pergunta 4.3.1	Não ☐
	se SIM a alguma das perguntas acima, continue com a pergunta 4.2.11	
4.2.11	Quanto tempo usou regularmente (quase todos os dias) equipamento de protecção individual enquanto trabalhava?	
4.2.11.1	Óculos de protecção:	Anos ☐
4.2.11.2	Luvas:	Anos ☐
4.2.11.3	Máscara:	Anos ☐
4.2.11.4	Aventais:	Anos ☐
4.2.11.5	Outros	Anos ☐

Ocupação 3

4.3.1	Área/secção	
4.3.2	Título da ocupação	
	Dar uma breve descrição do trabalho	
4.3.3	Permanente/eventual:	
4.3.4	Quanto tempo trabalhou nesta ocupação?	Anos
		Meses
4.3.5	Em que área trabalhou?	
	a) Serração	
	b) Maquinaria	
	c) Montagem	
	d) Aplainação	
	e) Prefuração	
	f) Envernizamer	
	g) Pintura	
	h) Estofaria	
	i) Gravura	
	j) Limpeza	
	k) Loja	
	l) Transporte	
	m) Administraçã	
	n) Outros	
	Especificar:	
4.3.6	Com que tipos de madeira trabalhou?	
	Responder a uma ou mais perguntas, inserindo uma cruz (X)	
	a) Jambire	Sim
		Não
	b) Chanfuta	Sim
		Não
	c) Umbila	Sim
		Não
	d) Mecrusse	Sim
		Não
	e) Umbaua	Sim
		Não
	f) Pinho	Sim
		Não

	g) Sândalo africano	Sim ☐ Não ☐
	g) Cordila africana	Sim ☐ Não ☐
	h) Zebra	Sim ☐ Não ☐
	i) Missanda	Sim ☐ Não ☐
	k) Outros	Sim ☐ Não ☐
	Especificar:	
4.3.7	Quanta poeira você diria que esta ocupação produzia:	
	Dar todas as opções de uma só vez ***nserir uma cruz (X) ao lado de uma resposta somente***	
	a) Sem poira	☐
	b) Pouca	☐
	c) Uma quantidade média	☐
	d) Muita	☐
4.3.8	O seu trabalho envolvia actividades de limpeza?	Sim ☐
	Dar todas as opções de uma só vez ***se SIM, continue com 4.3.8 (um ou mais), se NÃO vai para 4.3.9***	Não ☐
4.3.8.1	Limpeza geral	Sim ☐ Não ☐
4.3.8.2	Limpeza dos equipamentos	Sim ☐ Não ☐
4.3.8.3	Limpeza do equipamento de protecção individual	Sim ☐ Não ☐
4.3.8.4	Outro	Sim ☐ Não ☐
	Especificar:	
4.3.9	Quão longe trabalhava da fonte da poeira?	
	Dar todas as opções de uma só vez ***Inserir uma cruz (X) ao lado de uma resposta somente***	
	a) Ao lado da fonte	☐
	b) Aproximadamente 1-2 metros	☐
	c) Mais de 3 metros de distância	☐
	d) Não se aplica	☐
4.3.10	Usava regularmente (quase todos os dias) algum equipamento de protecção individual enquanto fazia o seu trabalho?	Sim ☐ Não ☐
	se N ÃO, salte para a pergunta 4.4.1 ***se SIM, continue com a pergunta 4.3.10***	

4.3.10.1-5	Qual dos seguintes equipamentos de protecção individual usa regularmente (quase todos os dias?)		
4.3.10.1	Óculos de protecção:	Sim	
		Não	
4.3.10.2	Luvas:	Sim	
		Não	
4.3.10.3	Máscara:	Sim	
		Não	
4.3.10.4	Aventais:	Sim	
		Não	
4.3.10.5	Outros:	Sim	
	se NÃO a todas as perguntas anteriores, salte para a pergunta 4.4.1	Não	
	se SIM a alguma das perguntas acima, continue com a pergunta 4.3.11		
4.3.11	Quanto tempo usou regularmente (quase todos os dias) equipamento de protecção individual enquanto trabalhava?		
4.3.11.1	Óculos de protecção:	Anos	
4.3.11.2	Luvas:	Anos	
4.3.11.3	Máscara:	Anos	
4.3.11.4	Aventais:	Anos	
4.3.11.5	Outros:	Anos	

<u>História ocupacional anterior</u>

5 Enumere todos os locais de trabalho onde trabalhou anteriormente, antes de vir trabalhar nesta empresa:

Começar com o emprego mais recente para trás (incluindo todas as empresas e trabalhos feitos)

Nome da empresa	O que a empresa fazia	Título do trabalho (que você fazia)	Data de início (Ano)	Data de término (Ano)	Total de anos

OBRIGADO POR RESPONDER O QUESTIONÁRIO

Nome do entrevistador: ____________________

Data da entrevista: Dia ____ Mês ____ Ano

Appendix 4: Exhaled nitric oxide / LFT pre-test data collection sheet

UCT/UEM - WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY - 2017

EXHALED NITRIC OXIDE /LFT PRE-TEST DATA COLLECTION SHEET

Card 1

Survey Number ____________________ 1-3

A. IDENTIFICATION DATA

1.Surname ________________________________

2. First name/s ________________________________

3. Work number ________________________________ 4-9

4. Date of birth: Day____Month_____Year____ 10-15

5. Interviewer's initials __________________ 16

6. Date of interview:

Day___Month_______Year_____ 17-22

7. Company: ____ 23-24

B.HEALTH PROBLEMS

<u>Recent chest infections</u>

1. Have you had the flu, sinusitis or a chest infection in the past 3 weeks? 25

Yes	(1)
No	(2)

2. Are you being treated for Tuberculosis (TB)? 26

Yes	(1)
No	(2)

2.1 If yes, for how long? _______months _______weeks 27-30

If YES, to question no 2, indicate to person that the tests will not be done today. Schedule another appointment in three months time since the start of TB medication. If the person has already had three months of treatment, proceed with the rest of the screening questions and the post-bronchodilator test.

3. Have you had a heart attack or stroke in the last month?

Yes	(1)	☐	31
No	(2)		

4. Do you have epilepsy?

Yes	(1)	☐	32
No	(2)		

5. Have you had an operation on your brain, eyes, chest or stomach (in the last 12 months)?

☐ 33
☐☐ 34-35

If **YES** to any of the above **Q3-5**, indicate to the person that the lung function tests will not be done. If NO, proceed with the rest of the screening questions

6.For women:

6.1 Are you Pregnant?	Yes	(1)	☐	36
	No	(2)		
6.2 Are you Breastfeeding?	Yes	(1)	☐	37
	No	(2)		

If **Pregnant**, indicate to the person that the **Lung Function Test will not be done** today, but proceed with NIOX

If **Breastfeeding**, proceed with Lung Function Test with Post-Bronchodilator. Proceed with the rest of the screening questions.

C. ALCOHOL CONSUMPTION

1. Do you drink alcohol?

Yes	(1)	☐	38
No	(2)		

1.1 If yes, when have you last consumed alcohol?

1-2 hours ago	(1)	☐	39
1 day ago	(2)		
1 week ago	(3)		

1.2 How much alcohol did you consume?

_______________________________________ 40-41

D. MEDICATION USAGE (show booklet)

1. Are you taking any medicine/s from a doctor or clinic at the moment for asthma, and or hayfever?

Yes (1)

No (2)

42

1.1 If yes, what are you taking and when last did you take them?

Names — No. of hours since last dose

______________________________ ____________

________________ ________________ ____________

________________ ________________ _____________

43-44

45-46

47-48

2. Are you taking any medicine/s from a doctor or clinic at the moment for any heart condition, or your eyes?

Yes (1)

No (2)

49

If short-acting beta-2-agonist or anti-cholinergic inhalers used in the **last 4** hours or long-acting MDI or theophylline used in **last 8** hours, reschedule spirometry and counsel accordingly.

E. GREEN VEGETABLE CONSUMPTION

1. How often do you eat the following vegetable products?

Type of product	**Daily**	**1 to 3 times a week**	**1 to 3 times per month**	**Never**
1.1 Green salad	1	2	3	4
1.2 Spinach & other green leafy vegetables	1	2	3	4

50

51

2. When did you last consume green salad and/or spinach/other green leafy vegetables?

1-2 hours ago (1)

1 day ago (2)

1 a week ago (3)

52

F. PHYSICAL ACTIVITY

1. Do you exercise?

Yes (1)

No (2)

53

2. When was the last time you exercised?

1-2 hours ago (1)

1 day ago (2)

1 week ago (3)

54

G. SPIROMETRY/LUNG FUNCTION TEST

1. Have you ever had a spirometry/lung function test?

Yes	(1)	55
No	(2)	

2. If yes, when last did you blow into a lung function machine?

1-2 hours ago	(1)	56
1 day ago	(2)	
1 week ago	(3)	
> a week ago	(4)	

H. RECENT FOOD INTAKE

1. Did you drink coffee, tea or coca-cola in the last 6 hours?

Yes	(1)	57
No	(2)	

2. Did you have anything to eat or drink in the last hour?

Yes	(1)	58
No	(2)	

3. Have you smoked in the last hour?

Yes	(1)	59
No	(2)	

If YES to Question 2 or 3, reschedule test for at least 1 hour later the same day or another date.

Appendix 5: Lung function data collection

UCT/UEM - WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY – 2017
LUNG FUNCTION TESTS DATA COLLECTION SHEET

CARD 1

Record Number	[ ][ ][ ]	1-3
Work number	[ ][ ][ ][ ][ ][ ]	4-9
Date	[ ][ ][ ][ ][ ][ ] DAY MONTH YEAR	10-15

1. Subject’s blood pressure — systolic; diastolic

2. Subject's age — YEARS — 16-17

3. Subject's gender — MALE FEMALE — 18

4.1 Subject's height — CENTIMETRES — 19-21

4.2 Subject's weight — KILOGRAMS — 22-24

5. When did you last work in this company? Date — 25-30

BASELINE SPIROMETRY

6. **PREDICTED FEV_1** — 31-33

7. **INITIAL FEV_1 and FVC**
(up to 8 attempts)

	FEV_1	FVC	
1			34-39
2			40-45
3			46-51
4			52-57
5			58-63

7.1 Number of rejected attempts — 64

8. **Best INITIAL FEV_1 as % of predicted FEV_1** — 65-67
(divide best results from No. 7 by results from No. 6)

BRONCHODILATOR CHALLENGE ONLY

9. **FEV_1 and FVC**

	FEV_1	FVC	
9.1 Record Best two technically satisfactory Manoeuvres (up to 8 attempts)	☐ ☐☐	☐ ☐☐	68-73
	☐ ☐☐	☐ ☐☐	74-79

9.2 Number of rejected attempts ☐ 80

CARD 2

10. **Best POST-BRONCHODILATOR FEV_1 as % of initial FEV_1** ☐☐☐ 1-3

(divide best results from No. 9 by best results from No. 7)

11. General comments:

____

____

____

12. Technologist initial's _______________ ☐ 4

13. Room temperature: _______________ ☐☐ 5-6

(degrees celcius)

14 Lung function record appended NO ☐ YES ☐ 7

Appendix 6: Exhaled nitric oxide data collection sheet

UCT/UEM - WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY - 2017

EXHALED NITRIC OXIDE DATA COLLECTION SHEET

			Card 1
Survey Number	________________________		1-3
Date:	_________________________________		
Time	____________________		
Ambient NO concentation (ppb)	___________________		4-6
Ambient temperature (graus celcius)	__________________		7-8
1. Subject's bloob pressure	systolic	___________	9-11
	diastolic	___________	12-14
2. Subject's age (in years)	___________________		15-16
3.1 Subject's heigth (in centimentres)	___________________		17-19
3.2 Subject's weight (in kilograms)	___________________		20-22
4. Gender:	Male	(1)	23
	Female	(2)	
5. Effort number (start)	____________		24-26
6.1 FENO measurement (ppb) 1st effort		____________	27-29
6.2 FENO measurement (ppb) 2nd effort		____________	30-32
If there is a discrepancy of > 10 ppb between 1st & 2nd efforts, perform a 3rd effort			
6.3 FENO measurement (ppb) 3nd effort		____________	33-35

Appendix 7: Questionnaire for Manager/Supervisor on wood dust control methods in the factory

UCT/UEM - WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY

Questionnaire for Manager/Supervisor on wood dust control methods in the factory during the time of the dust survey done in 2016

Thank you for participating in the wood dust survey that we conducted in your factory. We are currently compiling the report and would like to ask you a few questions about **wood dust control in the factory during the time when the survey was done**. It will take me less than 5 minutes to ask you these questions.

1. Did you provide training at this factory for workers on how to protect themselves from the health effects of wood dust exposure?

a) Yes ☐
b) No ☐

2. What methods did you use for cleaning up the wood dust contamination of floors and machines in the factory? More than one answer is possible

a) cleaning with compressed air ☐
b) Dry sweeping with a broom ☐
c) Wet clean-up methods ☐

3. What methods did you use to clean off the wood dust on machines during maintenance work?

a) Damp rags ☐
b) Dry rags ☐
c) Both

4. Were wet clean-up methods used at the time to prevent stirring up dust from the floor with lift trucks and other vehicles?

a) Yes ☐

b) No ☐

5. Were the machines (e.g. sawing, planing, drilling and other) enclosed?

a) Yes ☐
b) No ☐

6. Was local exhaust ventilation present for machines and tools?

a) Yes ☐
b) No ☐

7. What system for temperature control did you rely on in the factory? <u>More than one answer is possible</u>

a) Semi-closed building ☐
b) Opening windows ☐
c) Ceiling fans ☐
d) General air-conditioning ☐

8. How often were the cutting tools sharpened?

a) Only when necessary ☐
b) 1-3 times a week ☐
c) Every day ☐

9. When were the working surfaces and floors in the factory cleaned?

a) At the end of working day ☐
b) Twice during working shift ☐
c) Working surfaces and floors cleaned continuously in the day ☐

10. How often did you clean your working clothes?

a) Only when is necessary ☐
b) 1-3 times a week ☐
c) Every day ☐

11. How was the waste from the factory disposed? <u>More than one answer is possible</u>

a) In sealed bags ☐

b) Placed in open containers ☐

c) Disposed in the backyard of the factory ☐

12. Have you implemented ANY improvement in work practices or control measures <u>AFTER</u> we conducted the dust sampling in your factory? ☐ **Yes** ☐ **No**

If yes, specify ____
____

13. Which type/s of woods are processed in your factory?

a) Panga-panga — Yes ☐ No ☐

b) Mahogany-bean — Yes ☐ No ☐

c) African teak — Yes ☐ No ☐

d) Lebombo ironwood — Yes ☐ No ☐

e) African mahogany — Yes ☐ No ☐

f) Pine — Yes ☐ No ☐

g) African sandalwood — Yes ☐ No ☐

h) Mutondo — Yes ☐ No ☐

i) Zebrawood — Yes ☐ No ☐

j) Missanda — Yes ☐ No ☐

k) Messassa — Yes ☐ No ☐

l) Other — Yes ☐ No ☐

Specify ____

THANK YOU FOR YOUR COOPERATION IN ANSWERING THESE QUESTIONS

Appendix 8: Environmental data collection sheet no. 1

UCT/UEM - WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY - 2016

ENVIRONMENTAL DATA COLLECTION SHEET NO. 1

A) WORKER INFORMATION

NOTE: WORKER INFORMATION SHEET TO BE COMPLETED FOR EACH WORKER SAMPLED

SURVEY NUMBER		________		
1. DATE	Day_____Month________Year______			
2. COMPANY:	______________________________________			
3. NAME:	______________________________________			
4. GENDER:		MALE	1	
		FEMALE	2	
5. HAND OF PREFERENCE*:	1. LEFT			
		2. RIGHT		
		3. NO PREFERENCE		
(*side where PAS6 sampling head should be positioned)				
5. DEPARTMENT:				
	1	Sawing		
	2	Machinery		
	3	Setting		
	4	Planing		
	5	Driling		
	6	Varnishing		
	7	Painting		
	8	Upholstering		
	9	Carving		
	10	Sanding		

7. JOB TITLE:			☐
	1	Sawer	
	2	Machine operator	
	3	Assembler	
	4	Planer	
	5	Drillinger	
	6	Varnishing worker	
	7	Painter	
	8	Upholsterer	
	9	Wood carver	
	10	Wood sander	
8. How many hours per day do you work?		______ hours	☐☐
9. How many hours per week do you work?			
	___________ hours		☐☐
10. How many years have you worked in your current job?			
	____________years		☐☐

Appendix 9: Environmental data collection sheet no. 2

UCT/UEM - WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY - 2016

ENVIRONMENTAL DATA COLLECTION SHEET NO. 2

DUST MEASUREMENTS WITH PAS-6 SAMPLING HEAD

NOTE: COMPLETED FOR EACH WORKER SAMPLED

SURVEY NUMBER ____________

PUMP NO.	
PAS6 HEAD NO.	
SAMPLE NO.	
FILTER NO.	
START TIME	
END TIME	
DURATION (MINS)	
FLOW RATE (PRE)	litres
FLOW RATE (POST)	litres

GENERAL COMMENTS:

____

____

____

Appendix 10: Environmental data collection sheet no. 3

UCT/UEM - WORK-RELATED ASTHMA AMONG WORKERS IN THE MOZAMBIQUE WOOD PROCESSING INDUSTRY - 2016

ENVIRONMENTAL DATA COLLECTION SHEET NO. 3

WORKER TASK OBSERVATION INFORMATION

NOTE: WORKER INFORMATION SHEET TO BE COMPLETED FOR EACH WORKER SAMPLED

SURVEY NUMBER __________

1. DATE Day______Month_________Year_______

2. COMPANY: ____

3. NAME: ____

4. GENDER:

MALE	1
FEMALE	2

5. HAND OF PREFERENCE*: 1. LEFT
2. RIGHT
3. NO PREFERENCE

(*side where PAS6 sampling head should be positioned)

5. Which of following **tasks does the worker performs?**

Carpentry manual	1 Yes	2 No
Carving machine	1 Yes	2 No
Drilling manual	1 Yes	2 No
Drilling machine	1 Yes	2 No
Planing manual	1 Yes	2 No
Planing machine	1 Yes	2 No
Sawing manual	1 Yes	2 No
Setting	1 Yes	2 No

7. Did the worker **wear a mask** when performing these tasks?		
Carpentry manual	1 Yes	2 No
Carving machine	1 Yes	2 No
Drilling manual	1 Yes	2 No
Drilling machine	1 Yes	2 No
Planing manual	1 Yes	2 No
Planing machine	1 Yes	2 No
Sawing manual	1 Yes	2 No
Setting	1 Yes	2 No

UCT Template 2013

MATERIAL TRANSFER AGREEMENT

Made and entered into by and between

PAULINO SAMUEL CHAMBA

A natural person residing at Av. Maguiguana no. 210, Maputo - Mozambique with passport number: AB 95996

(hereinafter referred to as "**Provider**")

and

THE UNIVERSITY OF CAPE TOWN

A university incorporated in terms of the Higher Education Act, 1997, and the statute of the University of Cape Town, promulgated under Government Notice No. 1199 of 20 September 2002, whose administrative offices are located at Bremner Building, Lower Campus, Lovers' Walk, Rondebosch, 7700, South Africa herein represented by Roger Wallace, in his capacity as Contracts Manager of the University of Cape Town and he being duly authorised thereto

(hereinafter referred to as "**Recipient**")

(collectively hereinafter referred to as "**the Parties**" and individually as "**the Party**")

Signatures Removed

PREAMBLE

WHEREAS as part of his PhD studies at the Recipient, the Provider is engaged on a project titled "Work-related asthma among workers in the Mozambique wood processing industry" ("the Research Project")

In the course of conducting the project the Provider will be collecting serum samples for study subjects and environmental samples of wood dust obtained by monitoring the air of the workplace environment, ("the Original Material")

The Provider wishes to transfer the Material to the Recipient for purposes of continued analysis as part of the Project and also to be used for further research by the Recipient and has agreed to make the Material available to the Recipient upon the terms and conditions set out in this Agreement.

NOW THEREFORE THE PARTIES HEREBY AGREE AS FOLLOWS:

1. DEFINITIONS

In this Agreement, unless clearly inconsistent with or otherwise indicated by the context, the definitions set out herein below shall apply:

1.1 "**Agreement**" shall mean the arrangement between the Parties captured in this document, together with any annexures, which are incorporated herein by reference for the transfer of the Material;

1.2 "**Commercial Use**" means the sale, lease, license, or other transfer of the Material or Modifications for profit-making purposes;

1.3 "**Effective Date**" shall mean the date of last signature by the Parties hereto;

1.4 "**Material**" shall mean the Original Material, Progeny and Unmodified Derivatives. The Material shall not include modifications, or other substances created by the Recipient through the use of the Material which are not Modifications, Progeny or Unmodified Derivatives;

1.5 "**Modification**" shall mean substances created by the Recipient which contain or incorporate the Material;

1.6 "**Original Material**" shall mean serum samples for study subjects and environmental samples of wood dust obtained by monitoring the air of the workplace environment, which resulted from research at the Provider;

1.7 **"Progeny"** shall mean unmodified descendant from the Material, such as virus from virus, cell from cell, or organism from organism;

1.8 **"Provider"** shall mean the organisation providing the Original Material as identified hereinabove;

1.9 **"Unmodified Derivatives"** shall mean substances created by the Recipient which constitute an unmodified functional subunit or product expressed by the Original Material. Some examples include subclones of unmodified cell lines, purified or fractionated subsets of the Original Material, proteins expressed by DNA/ RNA supplied by the Provider, or monoclonal antibodies secreted by a hybridoma cell line;

1.10 **"Recipient"** shall mean the organisation receiving the Original Material as identified hereinabove;

1.11 **"Recipient's Investigator"** shall mean Prof. M Jeebhay;

1.12 **"Research Project"** means the research project titled: "Work-related asthma among workers in the Mozambique wood processing industry."

2. TRANSFER OF MATERIAL

2.1 The Material and any related information and know-how shall be transferred to Recipient upon or subsequent to the Effective Date.

2.2. Provider is transferring the Material to Recipient as a service for the sole purpose of enabling the Recipient Investigator to use the Material for internal, non-commercial research on the Research Project.

2.3 The Material is being provided at no cost, other than, if applicable, a reimbursement for the direct and indirect costs associated with the collection, preparation and/or shipping of the Material.

2.4 The Material is provided without any warranty, express or implied, including (without limitation) warranties of merchantability and fitness for a particular use and the Recipient acknowledges that the Material is experimental in nature. Provider does not warrant that the use of the Material will not infringe on any patent, copyright, trademark or other proprietary rights of third parties.

3. DURATION

This Agreement shall commence on the Effective Date and shall terminate after 3 years, which shall coincide with the completion of the Research Project unless extended by mutual written agreement. Permission to extend the term of this Agreement must be sought by the Recipient 3 (three) months before the expiry of this Agreement.

4. OBLIGATIONS AND RIGHTS OF THE RECIPIENT

4.1 The Material may not be used in human subjects, for clinical trials or for diagnostic purposes.

4.2 The Material (including any Modification thereof) may be transferred to other parties in order for those parties to contribute to the Research Project, provided that the conditions of this Agreement are passed on to the other party or parties through a material transfer agreement between those parties and the Recipient.

4.3. The Recipient shall keep the Materials secure at the Recipient's laboratory and ensure that no one other than the Recipient Investigator and authorised co-workers under the direct supervision of the Recipient Investigator have access to the Materials.

4.4 The Recipient Investigator and co-workers shall use the Material in accordance with good laboratory practice and the highest standards of skill and care and shall ensure compliance with any applicable laws and regulations governing the transportation, keeping or use of the Materials.

4.5 All experimental procedures carried out using the Material shall be documented by the Recipient.

4.6 Recipient agrees that it will furnish Provider's Material to persons within its organisation on a "need to know" basis and that all persons to whom proprietary information concerning the Material is furnished will have been made aware of the strictly confidential nature of such information.

4.7 Provider shall be appropriately acknowledged as the source of the Material in any oral presentation or written publication of Recipient and/or Recipient investigator reporting the use of the Material.

4.8 If the Recipient wishes to include in a publication any information which has been provided by Provider with the Material and which was clearly marked as "confidential" and "proprietary" at the point of disclosure ("Confidential Information"), the Recipient will request permission from Provider, providing a copy of the text 30 (thirty) days before publication takes place. This provision shall not apply to information which can be shown to have been known by the Recipient prior to disclosure, which becomes known to the Recipient by a third party who is under no obligation of confidentiality to Provider and/ or which becomes part of the public domain.

4.9 The Recipient will at its own cost return or dispose of all remaining Materials if so instructed by the Provider and shall supply the Provider with a report and outlines of any discoveries, results or comments in relation to the Research at the conclusion of the Research.

4.10 Recipient is not granted any license, right or option to commercially utilise the Material under any patent, copyright, trademark or equivalent rights of Provider. Legal title to the Material will remain with Provider, including any Material contained or incorporated in Modifications. Provider reserves the right to distribute the Material to other commercial or non-commercial entities and to use it for its own purposes.

4.11 Recipient will not use the Material, including any Modification thereof, for any Commercial Use, unless Provider has granted prior written consent. The granting of such consent shall be at the sole discretion of Provider. Recipient must obtain a licence from Provider prior to making any Commercial Use of any product or process derived from the Material through good faith negotiations with respect to the commercial application of the Material. For clarification purposes, Commercial Use does not apply to commercially funded academic research. Provider shall however be under no obligation to grant such a licence.

4.12 If research involving the Material results in an invention which may be commercially useful, Recipient will promptly make disclosure of the invention to Provider. The Parties agree to negotiate in good faith the terms of the ownership and the exploitation of such invention, based on the Parties' respective contributions.

4.13 The Recipient shall not file any applications for patents or other Intellectual Property rights made by the Recipient through the use of the Material without Provider's prior written notice.

4.14 Recipient assumes all liability for the safe use and handling of the Material in compliance with all applicable laws and regulations. The Recipient shall indemnify and hold Provider harmless against any claims arising from the use and/or handling of the Material.

5. LIABILITY

5.1 Provider will not be liable to the Recipient for any loss, claim or demand made by the Recipient, or made against the Recipient by any other party, due to or arising from the use of the Material by the Recipient, except to the extent the law otherwise requires.

5.2. The liability of either Party for any breach of this Agreement, or arising in any other manner out of the subject matter of this Agreement, will not extend to loss of business or profit, or to any indirect or consequential damages or losses.

6. TERMINATION

6.1 Provider may terminate this Agreement if the Recipient is in material breach of any of the terms of this Agreement and, where the breach is capable of remedy, the Recipient has failed to remedy such breach within 1 (one) month of service of a written notice upon the Recipient specifying the breach to be remedied.

6.2 Upon completion of the research project or earlier termination of this Agreement, the Recipient will discontinue all use of the Material, and upon Provider's direction, return or destroy the Material, unless permission to retain the Material is specifically provided in writing by Provider to the Recipient.

7. DISPUTE RESOLUTION

7.1 In the event of any dispute, controversy or claim arising under, out of, or in connection with this Agreement, the Parties shall endeavor to resolve such dispute through good faith negotiations and in the event of the Parties' failing to resolve such dispute, the dispute shall be referred to and finally settled by arbitration through the auspices of the Arbitration Foundation of South Africa. Nothing in this clause shall prevent a party from seeking interlocutory relief through courts of appropriate jurisdiction.

7.2 In the event that a Party unsuccessfully challenges the arbitrator's award, fails to comply with the arbitrator's award, or fails to comply with any interim measure of protection issued by any competent authority, the other party shall be entitled to cost of suit, including reasonable attorney's fees, for having to compel arbitration or defend or enforce the award or interim measure.

8. SERVICE OF LEGAL NOTICES

8.1 Any notice for legal purposes given under this Agreement: must be in writing and signed by a person duly authorised by the sender and must either be by registered post, by hand or fax to the address or fax number of the intended recipient in the Schedule. Depending on the method of sending the Notice, and unless otherwise proven, a Notice will be deemed given when delivered or after ten (10) days if posted locally, or thirty (30) days if posted internationally. A Notice sent by fax is given on receipt of a transmission control report from the dispatching machine. The addresses specified hereinbelow shall constitute the Parties' respective service addresses for service of legal notices in terms of this Agreement and shall be addressed either to the address given below or to such other address as may hereafter be specified in writing by the Parties:

8.1.1	If to Provider: (Legal)	Attention:	The Director: Research Contracts & IP Services University of Cape Town

Allan Cormack House
2 Rhodes Ave, cnr Main
Road, Mowbray
7700

8.1.2 If to Recipient: Attention: Paulino Samuel Chamba
Av. Maguiguana no. 210
Maputo - Mozambique

9. ENTIRE AGREEMENT

This Agreement is the complete and exclusive agreement between the Parties regarding its subject matter and supersedes any prior oral or written communications or understandings between the Parties related to its subject matter. No modification, amendment or waiver may be implemented without the written consent of both Parties.

AGREED TO FOR:

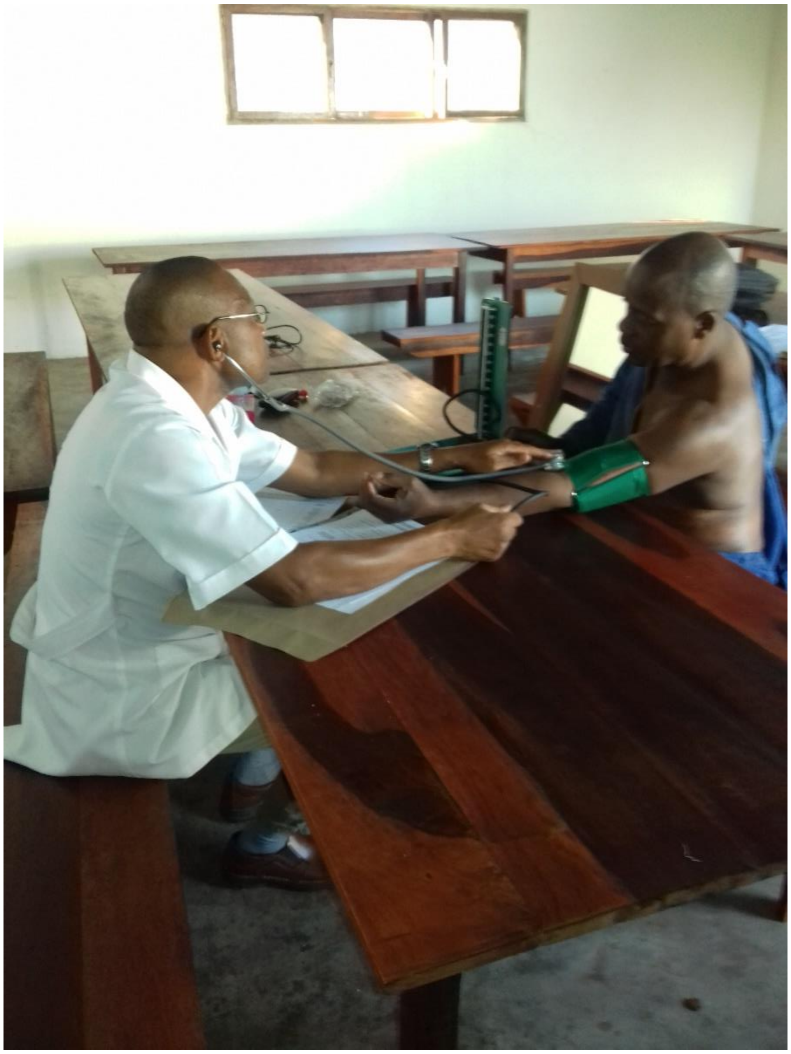
PROVIDER	**RECIPIENT**
Signature	Signature
Paulino Samuel Chamba	ROGER WALLACE
Name (duly authorised)	Name (duly authorised)
MD/PhD Student	CONTRACTS MANAGER
Position	Position
4th May 2015	5 MAY 2015
Date	Date

Appendix 12: Fieldwork pictures

Questionnaire interviews

Measuring height and weight

Blood pressure measurements



Exhaled nitric oxide test (FeNO)

Performing spirometry pre-bronchodilator

Bronchodilator administration

Spirometry post-bronchodilator

Blood collection

Urine samples

Allergies in the workplace

WORK-RELATED ASTHMA AMONG WORKERS IN THE WOOD-PROCESSING INDUSTRY: A REVIEW

P Chamba | MD, MPH
E Nunes | MD, PhD
Faculty of Medicine, Eduardo Mondlane University, Mozambique
Email | pschamba@yahoo.com.br

ABSTRACT

Various studies, including some in Africa, have reported an association between occupational exposure to wood dust and known probable asthma. Globally, the prevalence of asthma in woodworkers is between 5.6% and 18%; in Africa it is between 3% and 7%. This review focuses on epidemiological evidence from studies performed around the world to interrogate the evidence for the association between the exposure to wood dust and asthma. The review confirms a positive association between occupational exposure to wood dust and asthma. However, it has identified some limitations in the literature that relate to variable diagnostic criteria and epidemiological definitions for asthma: a lack of objective markers of asthma such as non-specific challenge tests and other inflammatory markers as well as markers for allergic sensitisation; understanding the pathophysiological mechanisms involved in the causation of asthma; limited number of studies of other agents present in wood dust such as endotoxins, glucans, terpenes and wood dust allergens; and the limited number of epidemiological studies investigating the dose–response relationships for allergens and other agents causing rhinitis and asthma among workers exposed to wood dust. These issues need to be addressed in future studies contemplating further investigation in this field.

This article has been peer reviewed.

INTRODUCTION

Wood is among the most important natural resources in the world and annually at least 1 700 million cubic metres are collated for industrial use.[1] Worldwide 12 000 tree species exist, and more than 1 000 of these are used for commercial purposes.[2] More than 52 types of wood species are grown in Mozambique.[3] The National Institute of Statistics (INE) (2011) estimated that at least 5 500 people are employed in 506 companies in the formal sector in Mozambique. The number of workers and companies in the informal sector is not captured by the INE estimates and is unknown, but is likely to be higher than that in the formal sector. This review was undertaken to better understand the respiratory health risks associated with exposure to wood dust in order to develop preventive strategies to reduce these risks.

WOOD PROCESSING AND HIGH-RISK WORK PROCESSES

The major wood-working processes are debarking, sawing, sanding, milling, lathing, drilling, veneer cutting, chipping and mechanical defibrating (Figure 1-4). From the tree-felling stage onwards through the various stages of woodworking and manufacturing processes, workers are exposed to airborne dust of different particle sizes, concentrations and compositions. Sawing and sanding both shatter lignified wood cells and break out whole cells and groups of cells (chips).[4] With increased cell shattering finer dust particles are produced. Sawing and milling are mixed cell shattering and chip-forming processes, whereas sanding is almost exclusively cell shattering. In hardwoods, the cells are tightly bound, resulting in more shattering and more dust. Similarly, dry wood leads to more dust formation. Softwood particles are more fibrous and usually larger and as a result less capable of becoming airborne.[4] Owing to their damp consistency, fungal or bacterial contamination occurs on a large scale when green or fresh wood is processed.

Considerably high heat generation during sawing, machining and sanding may change the chemical composition of wood dust. It has been reported that hardwoods give rise to finer airborne dust at a lower rate during sanding than softwoods, but that the total amount of airborne dust produced depends only on the total mass of wood removed, and not on the type of wood.[4]

Besides exposure to wood dust itself, wood workers are potentially exposed to various chemicals used in the different stages of the production process in the furniture industry, including glues (during assembling), dyes, solvents, dryers (in the finishing stage for painting), varnishes (in the finishing stage for polishing) and hardeners.

Figure 1: Carving and sawing wood

Figure 2: Drilling operations

Figure 3: Planing wood

Figure 4: Machine cleaning

CONSTITUENTS OF WOOD AND WOOD DUST

Wood is the hard fibrous substance composed mostly of the stem and branches of a tree or shrub, and covered by the bark. The inner core of the wood is referred to as 'heartwood' and the outer layer is called 'sapwood'. For industrial purposes, wood is classified into two types: hardwoods and softwoods. Softwoods are derived from coniferous trees (botanically named as *Gymnospermae* with exposed seeds), whereas hardwoods are derived from deciduous trees (botanically named as *Angiospermae* with encapsulated seeds).[4]

The major component (about 95% by weight) of wood is cellulose, hemicellulose and lignin.[2] Cellulose, which is built up exclusively of D Glucose units joined by β (1–>4) glycosidic linkages, is the major component (40–50%) of both hardwood and softwood. The remaining 5% comprises numerous other high and low molecular weight organic and inorganic compounds, including proteins, which can be extracted ('wood extractives'). These low molecular compounds include terpenes, terpene derivatives such as abietic acid, phenolic compounds, tannins, stilbenes, flavonoids and glycosides, many with known sensitising and irritative properties.[2]

Dust generated from wood processing is a heterogeneous mixture of inorganic and organic particles – wood fragments, viable and non-viable microorganisms, endotoxins, glucans, allergens, or mycotoxins – which are all potentially hazardous upon inhalation.[1]

EXPOSURE AND CAUSATIVE AGENTS

Furniture workers are exposed to several sensitisers or irritants including wood dust, 'wood extracts' (terpenes, terpene derivatives such as abietic acid and plicatic acid), endotoxins, glucans, isocyanate vapours and other chemicals (including glues, dyes, varnishes, paints, solvents and hardeners).[5,6]

Exposure assessment studies have demonstrated that workers in the wood-processing industry are exposed to variable concentrations of hazardous agents (microorganisms, endotoxins, glucans and terpenes) associated with wood dust. The exposure summary estimates reported in these studies have wide ranges, namely, wood dust particulate (0.05–12.0 mg/m^3, microorganisms (1.696–2,000 cfu/m^3 × 10^3), endotoxins (0.4–6.93 ng/m^3), glucans (3.5–18.9 ng/m^3) and terpenes (0.23–158 mg m^3).

As expected, dry mills had higher dust particulate levels than wet mills. In six of the 11 exposure studies evaluated[1,7,8,9,10,11] the threshold limit values for wood dust particulate recommended by ACGIH (2013) of 0.5 mg/m^3 for Western red cedar and 1 mg/m^3 for all other species was exceeded. There are currently no international exposure standards for other agents such as the glucans, endotoxins, terpenes and wood allergens found in wood dust.

AIRWAY DISEASE AND PATHOPHYSIOLOGICAL MECHANISMS

Exposure to wood dust and other causative agents associated with wood dust has long been associated with a variety of adverse health effects of the upper and lower airways. Health effects associated with exposure to wood dust and associated agents present in the upper airways include rhinitis, whereas in the lower airways it results in occupational asthma and general lung function deficits.[12]

The mechanisms for wood dust-causing asthma are far from fully understood.[13] For Western red cedar, a unique constituent, plicatic acid, has been shown to be a causal factor, and both immunological and non-immunological mechanisms are involved. For other types of wood no clear causal agent has consistently been found. Specific IgE sensitisation has been reported to be responsible for asthma in woodworkers; however, Type 1 allergy is not suspected to be a major cause of wood dust-induced asthma. Apart from IgE-mediated sensitisation, several other mechanisms, including irritative mechanisms, have been reported.

Animal studies have shown that wood components, such as the major constituent in pine resin – abietic acid – causes direct toxicity via lytic damage to alveolar, tracheal and bronchial epithelial cells. Wood-dust extracts from both hard and soft woods are able to induce the release of pro-inflammatory mediators from macrophages, express and induce the release of inflammatory mediators in human epithelial cell line, and modulate the expression of cytokines and chemokines.[13,24]

The oxidative products of monoterpenes or abietic acid can also cause airway inflammation through immune reactions. This was supported in an experimental study, which showed increased alveolar cell concentration, mainly macrophages in bronchoalveolar lavage (BAL) after exposure to concentrations of 450 ng/m^3.[13] Pylkkänen et al[14] studied the capacity of wood dusts to induce the production of reactive oxygen species (ROS) and caspase-3 activity in human bronchial epithelial cells. Dust from three wood species – pine, birch and oak – induced (ROS production. The study concluded that exposure to external particles may induce cellular apoptosis and necrosis of epithelial cells, which again may lead to shedding of the bronchial mucosa, to bronchial hyper-reactivity, and the exacerbation of asthma.

EPIDEMIOLOGY OF ALLERGIC SENSITISATION AND ASTHMA ASSOCIATED WITH WOOD DUST

The association between exposure to wood dust and asthmatic symptoms has been documented previously.[15]

A meta-analysis of wood-dust exposure and risk of asthma showed that the pooled relative risk (RR) of asthma among workers exposed to wood dust was 1.53 (95% CI 1.25–1.87). When the analysis was restricted to studies carried out on Caucasian populations, the pooled RR was 1.59 (95% CI 1.26–2.00), whereas the pooled RR of studies on Asian populations was 1.15 (95% CI 0.92–1.44).[16]

Table I reports on various epidemiological studies of asthma and other respiratory symptoms and the definitions used in these studies. While the prevalence of asthma in woodworkers globally based on various different definitions is between 5.6% and 18%, the prevalence in Africa appears to be lower: between 3% and 7%.[4,17,18,19] The prevalence of rhinitis appears to be much higher ranging, at between 16% and 33%.

The prevalence of asthma appears to be higher in dry sawmills (11.8%) compared to green sawmills (7.5%); however, the prevalence of symptoms appears to be higher in the green sawmills.[17] Woods species such as pine, mahogany, African teak, red cedar and imbuia are associated with a higher prevalence of asthma and rhinitis. Furthermore, fibre- and chipboards and mansonia are also associated with a high prevalence of rhinitis.

HOST RISK FACTORS

A. GENETICS

A meta-analysis of wood-dust exposure and risk of asthma conducted by Perez-Rios[16] demonstrated a higher risk of asthma among European and American studies than among Asian studies, indicating possible genetic factors in the development of asthma. This suggests the existence of interactions between genetic susceptibility to asthma and environmental factors. Several genetic factors are probably responsible for allergen sensitisation, which is determined by HLA genotype, including sensitisation to occupational agents.[27]

B. ATOPY

Schlünssen at al,[15] in their Danish study, demonstrated that asthma was associated with atopy, using clinical endpoints such asthma symptoms; OR = 4.2 (95% CI = 2.4–7.7) as well as asymptomatic bronchial hyper-responsiveness; OR = 7.4 (95% CI = 2.8–19.7).

C. UPPER AIRWAY SYMPTOMS

Occupational rhino-conjunctivitis often precedes the onset of IgE-mediated occupational asthma and it should be considered an important risk factor for the future development of occupational asthma, especially when high molecular weight agents are involved.[27] Occupational rhinitis is associated with an increased risk of asthma, although the proportion of subjects with occupational rhinitis who will develop occupational asthma remains uncertain.[28]

TABLE I: EPIDEMIOLOGICAL STUDIES OF WOOD WORKERS						
TYPE OF WORKFORCE (AUTHOR, COUNTRY)	DEPARTMENTS	N	OUTCOME MEASURE	WOODS IMPLICATED	PREVALENCE	DEFINITION OF ASTHMA AND RHINITIS
Sawmill plants (Ugheoke, Nigeria)[19]	Not stated	228	Respiratory symptoms	NR	Symptoms: Cough 35.1% Breathlessness 8.3% Wheezing 3.1%	NR
Furniture industry (Publio, Brazil)[20]	Furniture, painting and finishing	499	Respiratory symptoms	NR	Asthma 5.6% Rhinitis 16%	Asthma: Wheeze and attack of shortness of breath. Rhinitis: Nasal congestion, rhinorrhoea and sneezing.
Carpentry, sawmill plant (Aguwa et al, Nigeria)[21]	Carpentry, sawmill, carving and timber marketing	591	Occupational asthma and rhinitis	Mahogany, iroko, cedar and mansonia	Asthma 6.3% Rhinitis 78%	Asthma: Wheezing and breathlessness. Rhinitis: One or more of the following – sneezing, rhinorrhoea and/or nasal/pharyngeal itching.
Sawmill (Fox, South Africa)[8]	Dry mill – stress grading Wet mill – green chain, stacking and kilns	392	Asthma	Pine	Asthma: Definite 0.5% Probable 2.6% Possible 10.2%	Definite: Positive questionnaire and $\geq$15% improvement in FEV_1 post-salbutamol or on return from leave. Probable: Positive questionnaire and >10% and <15% improvement in FEV_1 post-salbutamol or on return from leave or doctor diagnosis of asthma. Possible: Positive questionnaire (except doctor-diagnosed asthma).
Furniture plant (Arbak et al, Turkey)[22]	Furniture decoration	64	Respiratory symptoms and peak expiratory flow rate	Fir tree (*Aberia mulleriana*)	Symptoms: Nasal 34.4% Cough 23.4 % Shortness of breath 18.8 % Chest tightness 15.6% Wheezing 14.1%	NR
Plywood and wood-working plant (Borm et al, Indonesia)[23]	Veneer preparation, veneer peeling, veneer drying, assembly, grading, composer and finishing	982	Respiratory symptoms, lung function, and nasal cellularity	Meranti	Symptoms: Cough 23.5 % Shortness of breath 4.1% Wheezing 1.6%	NR
Furniture factory (Milanowski et al, Poland)[6]	Sawing, trimming, sanding, plaining, and varnishing workshop	48	Work-related symptoms	Fibre- and chipboards	Symptoms: Cough 52.1% Shortness of breath 12.5% Asthma 6.2% Rhinitis 33.3%	Asthma: Specific inhalation challenge test. Rhinitis: Rhinorrhoea and nasal congestion.
Furniture factory (Schlünssen et al, Denmark)[25]	Sanding, cutting, assembling and packing	2507	Respiratory symptoms and lung function	Pinewood, particle board, hardwood, beech medium-density fibreboard, and mixed.	Asthma 6.3% Rhinitis 19.2%	'Yes' to: • At least one group A question (Have you been told by a doctor that you have asthma? Do you have asthma? Have you ever had asthma? Do you ever had wheeze?) **AND** • Two or more group B questions (Do you ever have chest tightness? Do you wake in the night with chest tightness? Do you wake in the night wheezing?).

TYPE OF WORKFORCE (AUTHOR, COUNTRY)	DEPARTMENTS	N	OUTCOME MEASURE	WOODS IMPLICATED	PREVALENCE	DEFINITION OF ASTHMA AND RHINITIS
Small-scale wood industries (Rongo et al, Tanzania)[9]	Planing, sawing, carving, and drilling	546	Respiratory symptoms and dust exposure	African teak, mahogany, bloodwood, East African camphor, East African afzelia.	Asthma 5–7%	Asthma: Asthmatic symptoms of shortness of breath with wheezing.
Sawmill (Douwes et al, New Zealand)[18]	Administration, green mill, planer mill, remanu-facturing and moulding	772	Asthma and other respiratory symptoms	Pine	Symptoms: Wheezing 29.6% Asthma: 18%	Asthma: Awoken by shortness of breath in past 12 months or asthma attack in past 12 months or current asthma medication.
Sawmill (Mandryk et al, Australia)[17]	Three green mills and two dry mills	87	Work-related symptoms	Eucalyptus	Symptoms in dry mill: Asthma 11.8% Cough 29.4% Breathlessness 8.8% Wheezing 8.8% Chest tightness 11.8% Symptoms in green mill: Asthma 7.5 % Cough 50.9% Breathlessness 24.5 % Wheezing 24.5% Chest tightness 28.3%	Asthma-like symptoms.
Furniture industry (Talini et al, Italy)[5]	Furniture manufacturing, spray painting and assembling	296	Asthma-like symptoms, bronchial hyper-responsiveness	Pine and beech	Asthma 7.7%	Asthma: Symptoms such as chronic cough, wheeze, attack of shortness of breath; Non-specific bronchial hyper-reactivity: PD20 <0.8 mg/ml.
Wood-processing factories (Alwis, Australia)[4]	Two logging sites, four sawmills, one major wood-chipping operation and five joineries	195	Symptoms	Eucalyptus, Pinus radiate, meranti (Shorea spp), Western red cedar (Thuja plicata), brushbox (Tristania conferata)	Symptoms: Breathlessness 17.4% Wheezing 22.6% Chest tightness 27.2% Asthma 10.8%	NR
Furniture plant (Shamssain, South Africa)[26]	Not stated	145	Pulmonary function and symptoms	Pine and medium-density board fibre wood	Symptoms: Nasal 49% Cough 43% Phlegm 15%	NR

NR: Not reported.

D. SMOKING

The relationship between smoking and occupational asthma is complex and contradictory. However, various studies have shown that smokers are at increased risk of developing sensitisation, although not necessarily asthma, due to agents that cause asthma through an IgE-mediated mechanism. Schlünssen,[15] in her study of asthma among atopic and non-atopic woodworkers, found that smokers were more often asthmatic, with OR = 3.6 (95% CI = 1.7–7.6) for work-related asthma symptoms and OR = 2.3 (95% CI = 1.0–5.4) for symptomatic bronchial hyper-responsiveness compared to non-smokers.

ENVIRONMENTAL RISK FACTORS

A. JOB DURATION

Aguwa et al,[21] in their study among woodworkers in south-eastern Nigeria, reported that the prevalence of occupational rhinitis and asthma among woodworkers increased with the duration of exposure. Among workers with less than two years' exposure, the prevalence of rhinitis was 8.7% and of asthma was 1.9%, whereas in workers with more than 10 years of exposure the prevalence of the rhinitis was 36.5% and that of asthma 6.5%.

Meo's[29] study among workers in small-scale wood industries found that the peak expiratory flow (PEF) in exposed workers was negatively associated with years of exposure. In workers with less than four years' exposure the PEF was 312.28 ± 23.62 ℓ/min compared to those with more than eight years, having a PEF of 177.00 ± 22.29 ℓ/min.

Shamssain et al[26] found that the prevalence of respiratory symptoms increases with the increase in the number of years of employment. Cough and nasal symptoms showed a pronounced increase with years of employment. The prevalence of cough in workers with 1–4 years of employment was 35%, whereas in workers with 9–12 years this was 66%. The prevalence of nasal symptoms in workers with 1–4 years of employment was 49% compared to workers with 9–12 years employment was 55%. The study also found that the proportion of subjects with an FEV_1/FVC ratio below 70% in the exposed group employed for 10–19 years was 56.2% compared to the 26.7% in the exposed group with less than 10 years of employment.

B. EXPOSURE LEVELS

Schlünssen and Schaumburg[15] found that symptomatic bronchial hyper-responsiveness was related to dust in a dose-dependent manner, with OR = 18.3 (2.0–170.8) when comparing the group with the highest (4.10 mg/m^3) to the lowest (0.17 mg/m^3) exposure level. The same tendency was seen for work-related asthma symptoms with OR = 6.4 (95% CI = 1.6-26.4).

Schlünssen and Schaumburg,[25] in their earlier study, reported that the prevalence of asthma and rhinitis increased with increasing of level of exposure. The prevalence of asthma in male workers exposed to wood-dust levels ranging between 0.0 mg/m^3 and 0.74 mg/m^3 was 3.9% compared to workers exposed to dust ranging between 0.74 mg/m^3 and 1.42 mg/m^3 which was 7.8%. Similarly, the prevalence of rhinitis in workers exposed to wood dust ranging between 0.0 mg/m^3 and 0.74 mg/ m^3 was 19.1% compared to workers exposed to wood dust ranging between 0.74 mg/m^3 and 1.42 mg/m^3, which was 22.3%.

Mandryk et al[17] demonstrated a relationship between exposure to endotoxins and glucans and work-related symptoms in workers at three green mills and two dry mills. The mean (GM) personal inhalable endotoxins (6.61 ng/m^3) and inhalable glucans (2.63 ng/m^3) exposures were high for the green mills (1.58 ± 1.52 ng/ m^3) compared with those of dry mills (0.38 ± 1.73 ng/ m^3), respectively. Green-mill workers showed a strong association between personal exposure and work-related symptoms. Significant relationships were found between glucan exposure and nasal congestion (OR = 62; 95% CI: 30.79–124.85), endotoxins and nasal congestion (OR = 49; 95% CI: 24.29–98.67), when the same logistic model was adjusted for endotoxins and glucans, respectively. Similarly, glucan exposure was associated with chronic bronchitis (OR 163; 95% CI: 71.52–368.71), as were endotoxins associated with chronic bronchitis (OR = 17; 95% CI: 7.92–36.23).

In a study of respiratory symptoms and dust exposure among male workers in small-scale wood industries in Tanzania, allergic symptoms were reported more commonly in the low-exposure group with OR = 2.4 (95% CI = 1.8–3.1) and the high-exposure group with OR = 2.7 (95% CI = 1.8–4.0), compared to control groups.[9]

A study of asthma and other respiratory symptoms in workers at a New Zealand pine-processing sawmill showed that working in sawmilling was associated with an increased prevalence of asthma and cough symptoms. Asthma symptoms in the exposed workers (18%) were more common than in the general population (12.1%), with adjusted OR = 1.6 (95% CI = 1.1–2.3). Asthma was also more common in the low-exposure group (15.6%) and high-exposure groups (high exposure to 'green dust' = 20.4% and 'dry dust' = 18.8%) than in non-exposed workers (9.2%). The respective adjusted odds ratios were OR = 1.9 (95% CI = 0.7–4.9), 2.7 (95% CI = 0.9–7.6), and 2.1 (95% CI = 0.8–5.7), respectively, but these were not significant. Adjusted odds ratios for symptoms of cough were OR = 2.7 (95% CI = 1.2–6.5) for the low, OR = 5.2 (95% CI = 2.1–13.0) for the high 'green dust' and OR = 3.3 (95% CI = 1.4–7.9) for the high 'dry dust' exposure groups compared to the non-exposed group.[18]

In an investigation into the increased incidence of respiratory symptoms among female woodworkers exposed to dry wood, the cumulative incidence proportion of daily coughing and chronic bronchitis was found to be associated with baseline wood-dust exposure in a dose- dependent manner. The risk estimates for daily coughing (with reference to the lowest exposure quartile) was OR = 1.6 (95% CI = 0.6–4.3), OR = 3.2 (95% CI = 0.9–6.8) and OR = 3.8 (95% CI = 1.5–9.7), respectively, in the second and third lowest and the highest quartile. The figures for chronic bronchitis were, accordingly, OR = 2.3 (95% CI = 0.4–14.5), OR = 3.0 (95% CI = 0.5–18.7) and OR = 6.0 (95% CI = 1.2–28.8).[30]

Kespohl et al found that obeche wood from Cameroon (called *ayous*) had less allergen content compared to obeche wood from Ghana (called *wawa*).[31] Further analysis showed that the reduced allergen content in *ayous* wood could be ascribed to a reduced amount of major obeche wood allergen Trip s 1. This emphasises the importance of using the content of wood dust allergens, and not only the concentration of airborne wood dust, in estimating dose– response relationships.[2]

PREVENTION STRATEGIES

Primary prevention of occupational asthma includes reducing exposure in order to prevent the development of respiratory disease in susceptible workers. Several studies support the view that reduction is likely to be followed by a concomitant reduction in disease burden and that use of personal protective equipment is the less effective measure in the hierarchy of controls against health hazards.[32] Control of exposure can be achieved by different control measures and the hierarchical strategy commonly applied is elimination, reduction, isolation, ventilation, avoidance of exposure and personal protection.[32] The preferred measure is substitution of an agent in the work process, for instance, the substitution of woods with strong sensitising potential with less strong sensitising woods. When substitution is not possible, exposure reduction, which is achieved in practice through a combination of different interventions, is the next best approach. It is important to define a desirable reduction in exposure and exposure standards can play an important role in this process.

Several organisations and countries have set standards or drawn up recommendations for limiting wood-dust exposure. The ACGIH has proposed a level of 0.5 mg/m^3 for Western red cedar and 1 mg/m^3 for all species [American Conference of Governmental Industrial Hygienists (ACGIH), 2013]. The Swedish exposure limit is 2 mg/m^3 for all types of wood.[33] In South Africa the occupational exposure limit for wood dust is 5 mg/m^3 (http://www.labour.gov.za/DOL/legislation/regulations/occupational-health-and-safety/regulation-ohs-hazardous-chemical-substances).

The intervention study conducted in Minnesota, United States, which included a combination of engineering, administrative, and behavioural components, has demonstrated that a combination of these measures can contribute to a reduction in the level of exposure. The median dust concentration at baseline in the original study was 5.87 mg/m^3 among intervention businesses and 6.23 mg/m^3 among comparison businesses. One year later, the median dust concentrations were reduced to 4.71 mg/ m^3 (a reduction of 19.8%) and 5.58 mg/m^3 (a reduction of 10.4%) from baseline in the intervention and comparison businesses, respectively.[34]

Hasle et al[35] have suggested that small enterprises have special problems that need to be considered when designing interventions for the work environment. The risk is higher and the ability to control lower due to limited human and financial resources. Tools and methods aimed at small enterprises may include different types of checklist (including both risk assessment and more action-oriented types), comprehensive health and safety management systems, and accident prevention. The most successful methods appear to be action-oriented, combining health and safety with other management goals, and based on trust and dialogue.[35]

RESEARCH GAPS

While this review confirms a positive association between occupational exposure to wood dust and asthma, it has identified some deficiencies in the literature that relate to methodological issues, including a lack of

- power due to small sample sizes, variable diagnostic criteria and epidemiological definitions for asthma;
- objective markers of asthma, including non-specific challenge tests and inflammatory markers;
- information on the actual wood species used in the production processes;
- detailed information about the concentrations of other agents present in wood dust such as endotoxins, glucans, terpenes and wood dust allergens, and
- epidemiological studies investigating the dose–response relationships for rhinitis and asthma among workers exposed to wood dust.

ACKNOWLEDGEMENTS

I would like to acknowledge the comments received from Prof Mohamed Jeebhay and Dr Roslynn Baatjies of the Centre for Environmental and Occupational Health Research at the University of Cape Town on previous versions of this manuscript.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interests.

REFERENCES

1. Gioffrè A, Marramao A, Iannò A. Airborne microorganisms, endotoxin, and dust concentration in wood factories in Italy. Ann Occup Hyg 2012;56(2):161–169.
2. Schluenssen V, Sigsgaard T, Raulf-Heimsoth M, Kespohl S. Workplace

exposure to wood dust and the prevalence of wood-specific sensitization. Allergologie 2012;35(8):402–412.

3. Bunster J. 52 madeiras de Moçambique. Eduardo Mondlane University. 1995.
4. Alwis KU. Occupational exposure to wood dust. 1998;328.
5. Talini D, Monteverdi A, Benvenuti A, Petrozzino M, et al. Asthma-like symptoms, atopy, and bronchial responsiveness in furniture workers. Occup Environ Med 1998;55(11):786–791.
6. Milanowski J. Work-related symptoms among furniture factory workers in Lublin Region (Eastern Poland). Ann Agric Env Med 2002;9:99–103.
7. Jacobsen GH, Schlünssen V, Schaumburg I, Sigsgaard T. Cross-shift and longitudinal changes in FEV1 among wood dust exposed workers. Occup Environ Med 2013;70(1):22–28.
8. Fox FH. An Epidemiological Survey of Asthma in a Pine Sawmill in South Africa. 2004.
9. Rongo LM, Besselink A, Douwes J, Msamanga GI, et al. Respiratory symptoms and dust exposure among male workers in small-scale wood industries in Tanzania. J Occup Environ Med 2002;44(12):1153–1160.
10. Hagström K, Axelsson S, Arvidsson H, Bryngelsson I, et al. Exposure to wood dust , resin acids, and volatile organic compounds during production of wood pellets. J Occup Environ Hyg 2008;5:296–304.
11. Spee T, Van de Rijdt-van Hoof E, Van Hoof W, Noy D, et al. Exposure to wood dust among carpenters in the construction industry in the Netherlands. Ann Occup Hyg 2007;51(3):241–248.
12. Meo S. Effects of duration of exposure to wood dust on peak expiratory flow rate among workers in small scale wood industries. Int J Occup Med 2004;17(4):451–455.
13. Jacobsen G, Schaumburg I, Sigsgaard T, Schlunssen V. Non-malignant respiratory diseases and occupational exposure to wood dust. Part I. Fresh wood and mixed wood industry. Ann Agric Env Med 2010;17:15–28.
14. Pylkkänen L, Stockmann-Juvala H, Alenius H, Husgafvel-Pursiainen K, et al. Wood dusts induce the production of reactive oxygen species and caspase-3 activity in human bronchial epithelial cells. Toxicology 2009;262(3):265–270.
15. Schlunssen V, Schaumburg I, Heederik D, Taudorf E, et al. Indices of asthma among atopic and non-atopic woodworkers. Occup Env Med 2004;61(6):504–511.
16. Pérez-Ríos M, Ruano-Ravina A, Etminan M, Takkouche B. A meta-analysis on wood dust exposure and risk of asthma. Allergy 2010;65(4):467–473.
17. Mandryk J, Alwis KU, Hocking AD. Effects of personal exposures on pulmonary function and work-related symptoms among sawmill. Ann Occup Hyg 2000;44(4):281–289.
18. Douwes J, McLean D, Slater T, Pearce N. Asthma and other respiratory symptoms in New Zealand pine processing sawmill workers. Am J Ind Med 2001;39(6):608–615.
19. Ugheoke AJ, Wahab KW, Erhabor GE. Prevalence of respiratory symptoms among sawmill workers in Benin City, Nigeria. Int Journal Trop Med 2009;4(1):1–3.
20. Publio A. Prevalence of respiratory symptoms among furniture factory workers, in Votuporanga-SP. The University of Campinas. 2008.
21. Aguwa EN, Okeke T, Asuzu MC. The prevalence of occupational asthma and rhinitis among woodworkers in south-eastern Nigeria. Tanzan Health Res Bull 2007;9(1):52–55.
22. Arbak P, Bilgin C, Balbay O, Yeşildal N. Respiratory symptoms and peak expiratory flow rates among furniture-decoration students. Ann Agric Env Med 2004;11:13–17.
23. Borm PJ, Jetten M, Hidayat S, Van de Burgh N, et al. Respiratory symptoms, lung function, and nasal cellularity in Indonesian wood workers: A dose-response analysis. Occup Environ Med 2002;59(5):338–344.
24. Määttä J. Chemokine Receptor Expression in RAW 264. 7 Mouse macrophages and in the lungs of mice after exposure to wood dust. 2008.
25. Schlünssen V, Schaumburg I, Taudorf E, Mikkelsen AB, et al. Respiratory symptoms and lung function among Danish woodworkers. J Occup Environ Med 2002;44(1):82–98.
26. Shamssain MH. Pulmonary function and symptoms in workers exposed to wood dust. Thorax 1992;47(2):84–87.
27. Jeebhay MF, Quirce S. Occupational asthma in the developing and industrialised world: A review. Int J Tuberc Lung Dis 2007;11(2):122–133.
28. Moscato G, Vandenplas O, Van Wijk RG, Malo JL, et al. EAACI position paper on occupational rhinitis. Respir Res 2009;10:16.
29. Meo SA. Effects of duration of exposure to wood dust on peak expiratory flow rate among workers in small scale wood industries. Int J Occup Med Environ Health 2004;17(4):451–455.
30. Jacobsen G, Schlünssen V, Schaumburg I, Sigsgaard T. Increased incidence of respiratory symptoms among female woodworkers exposed to dry wood. Eur Respir J 2009;33(6):1268–1276.
31. Kespohl S, Sander I, Schulze J, Poppe M, et al. Development of an obeche wood allergen quantification assay for the assessment of allergen exposure in workplaces. Scand J Work Environ Heal 2008;34(5):387–395.
32. Heederik D, Henneberger PK, Redlich CA. Primary prevention: Exposure reduction, skin exposure and respiratory protection. Eur Respir Rev 2012;21(124):112–124.
33. The Swedish Work Environment Authority. Occupational Exposure Limit Values. 2011.
34. Lazovich D, Parker DL, Brosseau LM, Milton FT, et al. Effectiveness of a worksite intervention to reduce an occupational exposure: The Minnesota wood dust study. Am J Public Health 2002;92(9):1498–1505.
35. Hasle P, Limborg HJ. A review of the literature on preventive occupational health and safety activities in small enterprises. Ind Health 2006;44(1):6–12.

References continued from page 104

pork kidney is related to IgE antibodies specific for galactose-alpha- 1,3-galactose. Allergy 2012;67:699–704. Arkenstål K, Sibanda E, Thors C, Troye-Blomberg M, et al. Impaired allergy diagnostics among parasite-infected patients caused by IgE antibodies to the carbohydrate epitope galactose-alpha-1,3-galactose. J Allergy Clin Immunol 2011;127:1025–1028.

6. Commins SP, Kelly LA, Rönmark E, James HR, et al. Galactose- alpha-1,3-galactose-specific IgE is associated with anaphylaxis but not asthma. Am J Respir Crit Care Med 2012;185:723–730.
7. Commins SP, James HR, Kelly LA, Pochan SL, et al. The relevance of tick bites to the production of antibodies to the mammalian oligosaccharide galactose–alpha-1,3-galactose. J Allergy Clin Immunol 2011;127:1286–1293.
8. Hamsten C, Starkhammer M, Tran TA, Johansson M, et al. Identification of galactose-alpha-1,3-galactose in the gastrointestinal tract of the tick ixodes ricinus: possible relationship with red meat allergy. Allergy 2013;68:549–552.
9. Perzanowski MS, Ng'ang'a LW, Carter MC, Odhiambo J, et al. Atopy, asthma and antibodies to Ascaris among rural and urban children in Kenya. J Pediatr 2002;140:582–588.
10. Drouet M, Sabbah A. The pork/cat syndrome or crossed reactivity between cat epithelia and pork meat. Monogr Allergy 1996;32:164–173.
11. Hilger C, Kohnen M, Grigioni F, Lehners C, et al. Allergic cross reactions between cat and pig serum albumin. Study at the protein and DNA levels. Allergy 1997;52:179–187.
12. O'Neil BH, Allen R, Spigel DR, Stinchcombe TE, et al. High incidence of cetuximab –related infusion reactions in Tennessee and North Carolina and the association with atopic history. J Clin Oncol 2007;25:3644–3348.
13. Chung CH, Mirakhur B, Chan E, Le QT, et al. Cetuximab-induced anaphylaxis and IgE specific for galactose-alpha-1,3-galactose. N Eng J Med 2008;358:1109–1117.