



Magnitude of occupational exposure to bagasse dust and associated factors among Metehara Sugarcane Factory workers, east Shoa, Ethiopia

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Received: 19 December 2017 / Accepted: 25 May 2018 / Published online: 16 June 2018
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Abstract

Background Occupational exposure to bagasse dust is known to pose direct and indirect costs to workers. However, the paucity of information on the extent of occupational exposure to sugarcane workers in Ethiopia is a challenge. Hence, the purpose of this study was to investigate the magnitude of occupational exposure to bagasse dust and associated factors.

Study area and period The study was conducted at Metehara Sugarcane Factory from February 15–May 15, 2017.

Study design A cross-sectional study design was employed among 552 participants. Data were collected using a structured questionnaire adapted from the National Institute of Occupational Safety and Health. In addition, the DustTrak™ Aerosol Monitor, CELL-880, brand name Casella, was used to measure exposure. Then, the data were entered and cleaned using Epi Info version 7 and exported to SPSS version 21 for analysis. Finally, the crude odds ratio (COR) and adjusted OR (AOR), together with their corresponding 95% confidence intervals (CIs), were computed. $p \leq 0.05$ was considered statistically significant in this study.

Results Lack of labor inspections and safety audits, lack of personal protective equipment (PPE), absence of job rotation, absence of ventilation, weekly working hours and job dissatisfaction were significantly associated, with AOR = 6.12 (2.52, 7.48), 7.17 (4.05, 8.87), 1.96 (1.27, 3.02), 3.63 (2.28, 5.78), 5.9 (3.64, 9.56), 6.34 (3.79, 10.62) and 2.19 (1.05, 4.57), respectively.

Conclusions Lack of safety audits and labor inspections, lack of PPE, absence of job rotation, absence of ventilation and current job dissatisfaction were found to be predictors of occupational exposure to bagasse dust. Hence, the identified factors should be considered to minimize exposure of sugarcane factory workers to bagasse dust.

Keywords Occupational exposure · Bagasse dust · Sugarcane · Safety audit · Ethiopia

Introduction

The first report on bagasse was published about a particle board factory in Egypt (Gehad et al. 1998). However, standards for bagasse exposure assessment are still lacking, except for the general recommendation limit from the National Institute of Occupational Safety and Health (NIOSH), which is 5 mg/m³ for any dust (Hearn 1968). These limits may not adequately protect workers from organic dusts contaminated

with microorganisms (Prather et al. 2016). Because the exposure limits are not known, massive health and socioeconomic burdens on workers (McClellan et al. 2010; NIOSH, OSHA 2010) are expected. For instance, Gascon et al. (2015) indicated the effect of sugarcane-related bagasse on workers' respiratory systems. The problem for sugarcane workers in the study area was severe because of the poor occupational health and safety measures in place. Sugarcane factory-related illness has been reported from developing countries (ILO and WHO 2010; Kassu and Daniel 2016). Moreover, the problem is expected to continue at an alarming rate given the industrialization and transformation policies in the sector. Periodic occupational exposure assessment was found important to limit exposure (CDC and NIOSH 2012; NIOSH and OSHA 2010; NIOSH 1977). However, this practice is not being carried out in Ethiopian sugarcane factories. Thus, it is essential to develop methods to estimate exposure in large- and small-scale industries as recommended by the CDC and NIOSH

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(2012). In Ethiopia, the extent of bagasse dust exposure is not known. Occupational symptoms, injuries and diseases are neither noted nor registered in the sugar industry sectors, and published works are based on self-report (Kassu and Daniel 2016; Osman and Kumie 2010). There has been indifference to the self-report findings. Exposure to very fine aerodynamic dust in the workplace causes a broad spectrum of adverse effects on workers' health, which may include respiratory irritation, allergic respiratory problems, nasal and lung cancer, eye irritation and skin rashes. These health effects are known to have remarkable short- and long-term implications for workers' health according to Prather et al. (2016).

In Ethiopia, particularly in the sugar industry sectors, there are no comprehensive statistics on occupational exposure to bagasse dust. The related literature indicates a lack of awareness among workers related to morbidity and mortality (Kassu J and K 2016). Therefore, this study contributes to the scarce data on the level of occupational exposure to bagasse dust in Ethiopia and also contributes to raising awareness about the potential of work-related morbidity and mortality using the following research questions and objectives:

- Research questions:

Is sugarcane workers' exposure to bagasse dust within the OHS standard?

What factors affect the magnitude of occupational exposure to bagasse?

- Objectives

To quantify the magnitude of bagasse exposure among sugarcane workers.

To investigate factors associated with the magnitude of occupational exposure to bagasse among sugarcane workers.

Methods

Study area and period The study was conducted at Metehara Sugarcane Factory, located 200 km east of the capital city, Addis Ababa, on the Addis-Djibouti road in the upper Awash Valley, from February 15–May 15, 2017. It is situated at 8 53'N and 39 52'E. Currently, the factory has a total concession area of 14,733 ha, of which about 10,300 ha is covered with cane plantation. The workforce includes professionals and manual laborers (Yohannes 2007).

Study design An industry-based cross-sectional study design was employed among 552 participants using a stratified sampling method to quantify the magnitude of occupational exposure to bagasse dust and also to investigate factors associated with the magnitude. The source population for this study was

all 7176 sugarcane workers, and the study units were selected sugarcane workers.

Data collection and tools A standardized structured questionnaire adapted from the National Institute of Occupational Safety and Health was used for data collection (CDC and NIOSH 2012). Additional data on occupational exposure to bagasse dust were collected using workplace hazard and risk analysis checklists. They included socioeconomic, behavioral, physical, work environment and job-related factors concerning bagasse dust exposure. To ensure quality, experts translated the NIOSH standardized questionnaire, adopted in English, to Amharic, the local language. The questionnaire was reviewed and revised to ensure internal validity. Pre-testing was done on 5% of the calculated sample size. Data collectors and supervisors were trained in the data collection tools and data collection procedure for 3 days. To ensure data completeness, 5% of the collected data was checked.

Dependent variable This was the magnitude of bagasse dust exposure.

Independent variables These were the socio-demographic, behavioral, physical, work environment and job-related factors.

After data collection, the data were entered and cleaned using Epi Info version 7 and then exported to SPSS version 21 for analysis. Logistic regression was employed to identify factors associated with the bagasse magnitude. All explanatory variables associated with the outcome variable in the bivariate analysis were included in the multivariable analysis. Binary logistic regression models of the multivariable analysis were employed to control confounders and the problem of multicollinearity. Hosmer-Lemeshow goodness of fit was used to assess whether the necessary assumptions for the application of multiple logistic regressions were fulfilled, with $p \leq 0.05$. Finally, the crude odds ratio (COR) and adjusted OR (AOR), together with their corresponding 95% confidence intervals (CIs), were computed. $p \leq 0.05$ was considered statistically significant in this study. In addition, the time-weighted average bagasse dust exposure level at different working sections was presented descriptively by comparison with the occupational safety and health administration (OSHA) permissible levels (Table 5) following the procedures below.

Measurement of bagasse dust exposure The level of bagasse variability experienced by individuals within the factory is often not well captured as part of exposure assessment in the country. The personal bagasse dust exposure approach addresses the limitations of current exposure assessment techniques by reducing misclassification at the level of the individual and by increasing precision by measuring dust exposure at a finer spatial scale. These approaches combine

information about the dust exposure, which helps describe where and when bagasse exposure may occur, with information about work patterns, behavioral, work environment and job-related factors that help explain who experiences bagasse exposure and how it happens. In this respect, the bagasse level of the different working sections was measured using the DustTrak™ Aerosol Monitor, CELL-880, brand name Casella, after calibration. Full-period single-sample measurement (one 8-h sample) was used, and the four highest concentrations were considered based on the recommendations of the CDC and NIOSH (2012). The time-weighted average was calculated using the following equation:

$$TWA = \sum_{i=1}^n \frac{C_i t_i}{t_1} \tag{1}$$

C_i is the concentration during the ith interval, and t₁ is the duration of the ith interval.

Ethical approval was obtained from the institutional review board of Mekelle University, College of Health Sciences, and a letter of support was written by the Ethiopian Sugar Corp. to Metehara Sugar Factory. All participants were informed about the objective of the study, participants were assured of confidentiality, and informed consent was obtained from the participants, who knew they were free to withdraw at any time.

Results

Socio-demographic characteristics

A total of 552 workers completed the questionnaire for a 99.1% response rate; 96.7% were males. About 66 (12%), 151 (27.4%) and 335 (60.7%) of the participants were daily laborers, permanent and contractual workers, respectively (Table 1).

Personal characteristics of study participants

This study revealed that the majority (380, 68.8%) of the respondents reported they did not use any personal protective equipment (PPE). The reasons stated for not using PPE were the factory did not provide it (93.5%), lack of awareness (67.8%), not feeling comfortable (67.6%) and decreasing work speed (66.8%). Of the total workforce, 404 (73.2%) study participants were dissatisfied with their current jobs (Table 2).

Job-related factors

Four hundred sixty-three (82.8%) of the workers reported the PPE provided to them was not the correct kind. Only 212 (38.4%) of respondents had health and safety training, and

Table 1 Socio-demographic characteristics of Metehara Sugarcane Factory Workers, East Shoa-Ethiopia, 2017 (n = 552)

Socio-demographic variables	Frequency	Percent
Sex		
Male	534	96.7
Female	18	3.3
Age group (in years)		
15–24	29	5.3
25–34	192	34.8
35–44	257	46.6
≥ 45	74	13.4
Marital status		
Single	48	8.7
Married	502	90.9
Divorced	2	0.4
Educational level		
Read and write	17	3.1
Primary (1–8)	216	39.1
Secondary (9–12)	193	35
College diploma	103	18.7
Degree and above	23	4.2
Working experience		
< 1 year	16	2.9
1–5 years	85	15.4
6–10 years	209	37.9
≥ 11 years	242	43.8
Employment pattern		
Daily laborer	66	12
Contractual	335	60.7
Permanent	151	27.4

484 (87.7%) participants reported the absence of working section inspection (Table 3).

Work environment characteristics

Of the total participants, 382 (69.2%) reported, their working environment was unsafe. Three hundred sixty-six (66.3%) reported working for more than 48 h per week (Table 4).

Magnitude of occupational exposure to bagasse dust

Based on the DustTrak™ Aerosol Monitor CELL-880 measurement, 380 (68%) workers were exposed to excessive bagasse dust. In this study, the mean bagasse dust concentration measured at each working section in the factory ranged from 1.52 to 10.34 mg/m³. Relatively, the lowest bagasse dust concentration was measured in the maintenance (1.26 mg/m³) and workshop sections (1.64 mg/m³). The highest bagasse dust

Table 2 Personal characteristics of Metehara Sugarcane Factory workers, East Shoa, Ethiopia, 2017 (*n* = 552)

Variables	Frequency	Percent
Frequency of alcohol drinking		
Never	325	58.9
Regularly	177	31.1
Sometimes	50	9.1
Frequency of chewing chat		
Never	341	61.8
Regularly	190	34.4
Sometimes	21	3.8
Sleeping disorders		
Yes	174	31.5
No	378	68.5
Wearing of available PPE		
Yes	172	31.2
No	380	68.8
Obeying safety notices		
Yes	166	30.1
No	386	69.9
Pre-placement and periodic medical examination		
Yes	103	18.7
No	449	81.3
Aware of unsafe acts and conditions		
Yes	207	37.5
No	345	62.5
Satisfaction with current job		
Yes	148	26.8
No	404	73.2
Years of service		
1–5 years	196	35.5
≥ 5 years	356	65.5

concentration was measured in the boiler section (10.34 mg/m³) (Table 5).

Factors associated with occupational exposure to bagasse dust

Results from multivariable binary logistic regression analysis showed that workers who were working in an area that did not have labor inspections were six times more likely to be exposed to bagasse dust than their counterparts (AOR = 6.12; 95% CI, 2.52, 14.88). Similarly, workers without personal protective devices were at 40% greater risk of exposure than those who use PPE (AOR = 1.96; 95% CI, 1.27, 3.02). Workers in areas with no systems for safety auditing were seven times more likely to be exposed to bagasse dust than those with systems audits (AOR = 7.17; 95% CI = 4.05, 8.87).

Table 3 Job-related factors reported by Metehara Sugarcane Factory workers, East Shoa, Ethiopia, May 5, 2017 (*n* = 552)

Variables	Frequency	Percent
Provision of correct PPE		
Yes	95	17.2
No	457	82.8
Health and safety training		
Yes	212	38.4
No	340	61.6
PPE use and risk assessment enforcement		
Yes	89	16.1
No	463	83.9
Job rotation systems are practiced		
Yes	98	17.8
No	454	82.2
Routine health and safety inspections conducted		
Yes	214	38.8
No	338	61.2
Labor inspections have been conducted		
Yes	68	12.3
No	484	87.7
Safety audits have been conducted		
Yes	80	14.5
No	472	85.5

Table 4 Working environment characteristics of Metehara Sugarcane Factory workers, East Shoa, Ethiopia, 2017 (*n* = 552)

Variables	Frequency	Percentage
Working in an area of unsafe work conditions		
Yes	382	69.2
No	170	30.8
Weekly working hours		
< 48 h per week	186	33.7
> 48 h per week	366	66.3
Presence of ventilation systems		
Yes	67	12.1
No	485	87.9
Job/working section categories		
Milling section	36	7
Boiler section	105	19
Maintenance	49	9
Power turbine	102	18.5
Evaporation plant	99	17.9
Sulfur station	12	2.3
Vacuum plant	38	6.8
Workshop	44	7.9
Centrifugal section	38	6.8
Sugar packing	29	5.3

Table 5 Level of bagasse dust exposure measurements of different working sections among Metehara Sugarcane Factory workers, East Shoa, Ethiopia, 2017 ($n = 552$)

Location	Respirable dust (in mg/m ³)						OSHA PEL
	Sample 1	Sample 2	Sample 3	Sample 4	Mean	TWA 8 h	
Milling section	10.572	10.32	9.926	9.23	10.01	9.98 mg/m ³	5 mg/m ³
Boiler section	15.18	9.423	8.96	7.8	10.34	10.34 mg/m ³	
Maintenance	1.73	1.25	1.007	0.992	1.24	1.26 mg/m ³	
Power turbine	9.326	8.95	7.07	5.64	7.74	7.74 mg/m ³	
Evaporation	6.57	5.613	5.422	4.51	5.52	5.52 mg/m ³	
Sulfer station	3.67	3.02	2.93	2.063	2.92	2.92 mg/m ³	
Vacuum plant	5.690	5.54	4.99	4.87	5.27	5.27 mg/m ³	
Workshop	2.01	1.59	1.51	1.47	1.64	1.64 mg/m ³	
Centrifugal	4.514	4.35	3.81	2.77	3.86	3.86 mg/m ³	
Door/diffuser	7.997	7.69	6.87	5.62	7.04	7.04 mg/m ³	

PEL permissible level, TWA Time weighted average

Moreover, the odds of having occupational exposure to bagasse dust in an area with no ventilation were 5.9 times higher than the odds of workers working in an area with ventilation (AOR = 5.9; 95% CI, 3.6, 9.5). Having training in health and safety was a protective factor against the occurrence of occupational exposure to bagasse dust [AOR = 0.68, 95% CI: 0.24(0.11, 0.52)]. Engagement in more than 48 working hours per week was a risk factor for the occurrence of occupational exposure to bagasse dust (AOR = 6.34; 95% CI 3.79, 10.62) (Table 6).

Discussion

Sugarcane-related industries are considered a way out of poverty in some countries, including Ethiopia. In this respect, Brazil is the best example, being a major producer of sugar and alcohol internationally (Clark et al. 2017; Sales and Lima 2010). A similar trend is aggressively followed in areas with persistent poverty such as Ethiopia. However, the production process generates bagasse as a waste material, exposing sugarcane workers and the surrounding communities to health hazards. This study revealed that 68.8% (95% CI, 64%–72%) of Metehara Sugarcane Factory workers are exposed to bagasse dust above the permissible occupational exposure limits. A relatively higher concentration was reported from a Thai study by Le Blond et al. (2017) with an exposure level of 89.4%; Costa Rica accounted for 78% (Gascon et al. 2015). The variation in exposure levels could be related to the source population involved in the study; the previous studies considered both sugarcane harvesters and factory operation, while the present study includes only factory workers. In addition, methodological differences (methods of data collection and number of samplings) also could be a factor. The previous study depended on repetitive large numbers of samplings taken from the area and personal sampling with full-period

consecutive sampling strategies, unlike the present study, which depends only on area sampling with full-period single-sampling strategies. However, the exposure levels in the current and previous studies indicated the potential for health hazards according Le Blond et al. (2014) because of its composition. In agreement with the above, Gascon et al. (2012) reported that the prevalence of wheezing and eye problems almost doubled in workers exposed to bagasse and other types of dust, with a notable increase in shortness of breath and rhinitis among bagasse-exposed workers. Understanding the potential and identified occupational hazards, scientists in the field are working to convert bagasse to useful products, for example, as an ingredient in fertilizer for sugarcane plantations, pozzolans in cements and concretes, and geopolymers (Clark et al. 2017). There are also other recommendations, such as using it as a filler in clay bricks, to enhance the possibility of reusing it in a safe and sustainable way (Faria et al. 2012). Despite the findings and recommendations in the literature, Ethiopian sugarcane factories are far from recognizing the occupational hazards for the workers and surrounding communities associated with bagasse. This is explained by the absence of a particulate matter emission control technique in areas where workers are exposed to bagasse dust for prolonged times. In addition, absence of administrative control (job rotation, reducing the duration of stays in dust-prone work sections) and lack of routine power turbine machine inspection in conjunction with timely corrective action are also predominant factors related to the occurrence of high dust exposure in the study area. In line with the above, bagasse dust concentrations above the permissible exposure limit (5 mg/m³) were most often measured in the boiler section (10.34 mg/m³) and milling section (9.98 mg/m³) (Le Blond et al. 2017). This is lower than the rate reported in Thailand (21.6 mg/m³) (Pompun et al. 2011). This difference could be due to the large number of sugarcane stalks crushed and both respirable and inhalable dust sampled in

Table 6 Bivariate and multivariate analysis of predictor variables related to occupational exposure to bagasse dust among Metehara Sugarcane Factory workers, East Shoa, Ethiopia, 2017

Characteristics	Bagasse dust exposure	COR (95% CI)	AOR (95% CI)	<i>p</i> value
Weekly working hours				
< 48 h per week	91	142	1	
> 48 h per week	289	30	15.01(9.5, 23.7)	6.34(3.79, 10.62) 0.001
Satisfied with current job				
Yes	100	48	1	
No	280	124	1.08(1.04–1.62)	2.19(1.05, 4.57) 0.001
Available PPE utilization				
Yes	124	124	1	
No	256	48	1.25(1.03–1.86)	1.96(1.27, 3.02) 0.001
Health and safety training				
Yes	204	136	1	
No	176	36	3.25(2.14,4.95)	0.24(0.11,0.52) 0.043
Safety audit conducted				
Yes	73	12	1	
No	307	160	5.60(2.5,12.45)	7.17(4.05, 8.87) 0.034
Labor inspection conducted				
Yes	61	28	1	
No	319	144	1.01(1.16–3.06)	6.12(2.52, 7.48) 0.001
Job rotation systems practiced				
Yes	170	12	1	
No	210	166	2.37(1.93,4.58)	3.63(2.28, 5.78) 0.001
Ventilation systems exist				
Yes	354	131	1	
No	26	41	4.26(2.5, 7.24)	5.9 (3.6, 9.5) 0.003

*Significant at $p < 0.05$, bivariate analysis. **Significant at $p \leq 0.05$, multivariate analysis. 1 = Reference group

the previous study or may be due to the different sampling strategies employed.

Moreover, this study finds predictors influencing the occurrence of occupational exposure to bagasse dust. Accordingly, the lack of safety audits in the working section was a significant predictor of occupational exposure to bagasse dust compared with workers from an area where the safety audit was conducted (AOR = 7.17 (4.05, 8.87); $p \leq 0.05$). This may be due to lack of competent personnel at the factory level or non-adherence to the OSHA standards concerning the industrial code of practice among the factory administration. Similarly, the lack of labor inspections at work was also a significant predictor of occupational exposure to bagasse dust (AOR = 6.12; 95% CI, 2.52, 7.48; $p \leq 0.05$). This finding was similar to the issue briefing conducted in Ontario, Canada (Cameron 2012). In addition, job dissatisfaction was a significant predictor of occupational exposure to bagasse dust (AOR = 2.19; 95% CI; 1.05, 4.57; $p \leq 0.05$). This may be due to limited and inappropriate provision of personal protective equipment, limited safe work practice in the workplace and an extremely dusty environment. This finding was in agreement with the study conducted among small- and large-scale industries in Ethiopia (Tadesse and Israel 2016). Moreover, job rotation

was among the work components mentioned for improvement by Eskezia et al. (2016), unlike in this study.

Besides, non-use of personal protective equipment was also a significant predictor of occupational exposure to bagasse dust and workers who did not use personal protective equipment (AOR = 1.96; 95% CI, 1.27, 3.02; $p \leq 0.05$). This could be mainly due to the existence of a limited health and safety training culture in the country and insufficient attention given to appropriate and timely provision, lack of regulation and enforcement of personal protective equipment (PPE) by factory managers. Despite expectations, work-related injuries are assumed to be preventable with the provision of occupational health programs in workplaces (Molla et al. 2015). A similar study on occupational health and safety in the country indicated the lack of development or lack of resilience associated with handling the ever-growing demands for workers' health in the context of industrialization in Ethiopia (Kumie et al. 2016). Non-existence of job rotation in factories was also a significant predictor of occupational exposure to bagasse dust (AOR = 3.63; 95% CI, 2.28, 5.75; $p \leq 0.05$), despite its importance for work environment improvement according to Eskezia et al. (2016). Absence of ventilation systems at work was another significant predictor (AOR = 5.81; 95% CI 3.69,

9.52; $p \leq 0.05$). Similarly, implementation of basic occupational health and safety services including training in occupational health and safety seems highly advisable in factories to safeguard workers' health as recommended by Bogale et al. (2014). Indifference to these recommendations, lack of ventilation systems, proper job rotation, lack of PPE and lack of safety audits in the factory contributed high levels of exposure to bagasse dust in the study area.

Limitations of the study

The extent of personal bagasse dust exposure levels and their biological constituents in workers were not quantified.

Conclusions and recommendations

The extent of occupational exposure to bagasse dust associated with the sugarcane manufacturing process in Metehara Sugarcane Factory poses a potential hazard to workers' health and safety as well as organizational productivity. The levels of bagasse dust exposure measured were found to be higher than the permissible limit, and the major associated determinant factors were the lack of safety audits, lack of labor inspections, lack of personal protective equipment, absence of job rotation practice, absence of ventilation systems and job dissatisfaction. Thus, the identified factors should be considered for proper occupational health and safety implementation to safeguard workers' health.

Acknowledgments The authors thank Zewdu Girma and Sara, and other workers in the factory, for their support and collaboration, Dereje, the factory occupational hygienist, and the factory for giving us the opportunity to carry out this study. Thanks to Ashenafi Hailu, Fistum Birhanu and Fikru Keno for their help and advice on sampling materials and methods. We are grateful to the workers for their participation. Last but not least, we thank Mekelle University for the ethical clearance and financial support for data collection.

Author contributions All the authors made significant contributions to the proposal development, data collection, data analysis and manuscript preparation process of this work. All authors read and approved the final manuscript.

Compliance with ethical standards

Competing interests There is no competing interest in the presented data with any person or organization.

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