

Sugarcane Agro-Industrial Health and Safety with Particular Focus on Sudan: A Systematic Literature Review

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Abstract

Sugarcane is a vital cash crop grown in about 200 tropical and sub-tropical countries around the world. Due to its high rates of occupational diseases, accidents, and fatalities the agro industry is regarded as one of the most hazardous industries despite being one of the essential sectors globally regarding food supply and workforce. Most of the world's cane sugar crop is produced in Low- and Middle-Income Countries (LMIC), such as Sudan, where agriculture and farming are still the main sources of income and managing occupational health and safety is challenging. This systematic literature review aims to investigate the available research on occupational health and safety within sugarcane agro-industrial production and how Sudan fares in this domain. Moreover, it aims to see the significant issues sugarcane workers face during the cultivation and processing of sugar and its products following the reporting checklist of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (2020) as described in the literature. This systematic literature review included (n=21) peer-reviewed studies. The study found consensus among the studies reviewed that the process of manually cutting sugarcane and the burning process pose a tremendous risk on workers during the sugarcane harvesting phase. These two sequential processes expose workers to several risks responsible for health problems including respiratory, renal, cardiovascular, and dermatological. Because of such risks, the need for managing both processes and occupational safety in the sugarcane industry, and the need for more research regarding occupational health and safety in this industry is stressed.

Keywords: Sugarcane; Safety and Health; Developing Countries; Workers

Introduction

Sugarcane is the 14th most extensive crop in terms of cultivated area, with an estimated global production of 1.9 Gt, with Brazil and India accounting for 39% and 18% in 2013 [1] followed by Pakistan, China Thailand [2] and Sub-Saharan Africa [1].

Likewise, sugarcane is an important cash crop grown in about 200 tropical and sub-tropical countries worldwide [3]. It is a vital agro-energy crop since its residues are the most low-cost, sustainable biomaterials for bio fuel and power generation [4]. In the same view, sugarcane processing, an agro-based industry, is rising rapidly to produce sugar, bio ethanol, and related products [3]. Sugarcane is a particularly “high impact” crop with significant positive and negative environmental and socio-economic impacts, despite considerable diversity in production systems and contexts [1].

Sugarcane Production in Sub-Saharan Region

The Sub-Saharan Africa contributes to around 4% of global sugarcane production is considered a critical region for continued expansion due to its high production potential, low cost, and proximity to European markets which [1]. With the opportunity to a sustainable energy source by producing bio fuels and electricity, utilizing the enormous amounts of the sugarcane by product, bagasse [5]. Furthermore, the cost of sugarcane production in Sub-Saharan are relatively low due to the immaculate growing circumstances supporting high yield and conversion to sucrose [1].

See the distribution of sugarcane worldwide illustrated in Figure 1.

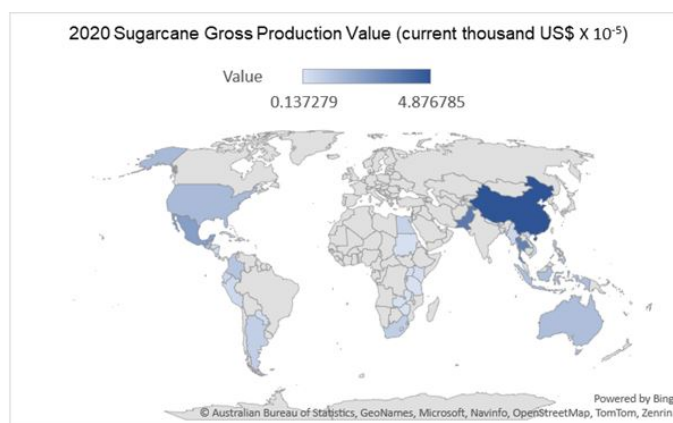


Figure 1: Source: [40]

None the less, sugarcane in the Sub-Saharan is coupled with various production techniques, management skills, and sugar economy models, including mega-estates, independent farmers, small-scale out-growers, and mixed models [1] Moreover, its production is associated with several positive and negative impacts on the environment and the economy in addition to the clear regional variations, in terms of challenges and opportunities [1,5]. [5] Discussed the difficulties that traditional sugar mills face including inefficient boilers, less effective back-pressure steam turbines, and inefficient and energy-intensive cane mill rollers [5]. In the same vein, [6] argued that among the challenges faced by small-scale sugarcane farmers in South Africa that contribute to low production and failure to meet industry standards are labor costs, poor agronomic practices, drought stress, and lack of funding [6]. From another point of view, poor management, corruption, and vested political interests are the challenges preventing Kenya's sugar industry from being more efficient and achieving self-sufficiency in sugar production.

In general, different Sub-Saharan African countries face different difficulties and possibilities, however, scholars suggest the use of fertilizer and mechanical maintenance to enhance sugarcane productivity [6].

Moreover, the sugarcane industry requires updating the mills to modern sugarcane mills that require a sizable financial investment, and enabling policy and legal measures, such as power purchase agreements, to buy excess power in a more environmentally friendly manner [5].

Sugarcane Production in Sudan

Sudan is the second among the five countries that account for more than half the total sugarcane production in the sub-Saharan countries [1]. The Food and Agriculture Organization (FAO) states that Sudan ranks 31st Globally in sugarcane production with a total value of 233062 US\$ (FAO, 2020). It has been noted that since the establishment of the first sugar factory in 1962 the domestic sugar industry has sustained a steady growth and expansion [7] becoming an integral economic pillar of the country [8,9]. There are six sugarcane factories in Sudan, five of which are owned by the government. The first governmental sugar scheme established was the Al Guneid sugar estate mill, where the farmers owned the land, and the sugar company owned the mill. Four governmental factories were established in the following 40 years. These are the Sennar, Assalaya, and White Nile sugar factories. Table 1 details the Sudanese factories' year of establishment and production capacities. It was not till the early 1980s that the first private investment company was established [9]. All the above-mentioned factories have been operating for four decades; however, the health and safety measures need to be improved/ examined thoroughly.

Table 1: The capacities of Sudanese Sugar Factories, planted areas, and years of establishment Source [7]

Sugar mill	Year of establishment	Estimated annual production capacity (tons)	Total Area Faddan (1.038 acres)
Gunied	1962	60.000	40
New-Halfa	1965	75.000	40
Sennar	1976	110.000	38
Assalaya	1980	110.000	44
Kenana	1981	300.000	94
White Nile Sugar	2004	450.000	-
Total estimated production		1.045.000	

Health and Safety in Sugarcane Agro-Industry

Despite being one of the essential sectors globally regarding food supply and workforce, the agro industry is regarded as one of the most hazardous industries due to its high rates of occupational diseases, accidents, and fatalities [10]. Since sugarcane production involves several operations, including planting, harvesting, and processing, during which, sugarcane workers are exposed to many occupational health and safety hazards [11]. Examples of hazards workers are exposed to during sugarcane plantation, including fertilizers, pesticides, noise, slips, trips, falls, dust/particles, motor vehicles, tractors, trucks, motorcycles, UV/solar, radiation, pets Power Take-Off (PTO), bending, lifting, twisting and more [12]. As for the harvesting phase and since sugarcane is harvested manually or mechanically [7], high rates of accidents and injuries were reported [11]. Such occupational accidents were associated with tractors', noise, dust power lines, drains, slips, trips, falls, snakes, rats, motor vehicles, cars, utilities, trucks UV solar, and radiation [12].

The third stage of sugar production is sugar refining, which is known to be a highly energy-intensive process, that involves two distinct operations processing, and refining [13]. During this, the sugar production workers are exposed to hazards such as power tools, electricity, flying steel, fragments from grinders, heat, hand tools, welding, air compressors, explosion, jacks, hoists, failure, chemicals, solvents, petroleum products, fire, general workshop hazards, noise, storage areas, slips, trips and falls, bench, and working areas [11] carcinogenic, bagassosis, and chronic infections [11].

The sugarcane producers of Australia reported 12 deaths on Australians' sugar cane farms between 1989 and 1992. With an average of 3 deaths per year, all incidents were associated with machinery [12]. Between 1992 and 1999, 826 sugar cane industry injuries were reported to Queensland workers' compensation out of which 24% were from mobile plant and transport, non-powered hand tools caused namely tractors, 12.3%, and 17.1% were due to exposure to material substances and chemicals. The average compensation for the above-mentioned incidents was estimated to be about \$550,000 annually [12].

Moreover, in a recently conducted global review that contained evidence from 27 countries [14], farmers have higher rates of suicide, depression, and anxiety when compared to the general population. In many Low and Middle-Income Countries (LMICs), agriculture and farming are the principal source of income; however, farmers' mental health usually receives limited care from health systems and below-par support and attention from employers and [14].

Likewise, most sugar mills have poor occupational health and safety measures, and inadequate policies and infrastructure. Therefore, the workers are exposed to workplace accidents, repetitive strain injury (RSI), and musculoskeletal disorders (MSDs) in the neck, upper back, lower back, and arms due to continuous movements [15].

However, it is believed that the potential impact of sugarcane production on human health is given modest consideration [16,17] argued that the distinction must be made between 'personal or occupational hazards which give rise to incidents as slips fall, vehicle accidents, and 'process safety incidents which can have catastrophic effects resulting in multiple injuries and fatalities as well as substantial economic, property and environmental damage [17].

None the less, stated that the majority of the world's cane sugar crop is produced In Low- and Middle-Income Countries (LMIC), and managing occupational health and safety is challenging due to the loosened occupational health and safety regulations and problems with reporting system [11]. Likewise, the sugarcane industry in Sudan has been suffering from all the above-mentioned challenges.

Health and Safety in the Sugarcane Industry in Sudan

There is clear evidence that the OSH management in Sudan is ineffective [18]. reasoned that, although there are many laws in place, the recurrence of occupational accidents in Sudan is a proof that OSH governance is ineffective [18]. None the less, in the very few studies that explored the factors associated with the poor OSH in Sudan, it was noted that the unstable economy and the political unrest are among that factor contributing to the poor OSH [19].

When it comes to occupational risk factors for sugarcane workers in Sudan, there is no research found that addresses the workers' safety in any possible way. Hence, this study aims to investigate the available research on occupational health and safety within sugarcane agro-industrial production and how Sudan fares in this domain. Moreover, it aims to delve into the significant obstacles the sugarcane workers face during the cultivation and processing of sugar and its products.

Methodology

This review aims to gather, describe, and categorize available research on occupational hazards facing sugarcane workers' health and safety. A systematic review following the reporting checklist of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (2020) described in [20] was followed.

Eligibility

The combination of search terms and synonyms used to identify the relevant studies includes sugarcane, sugar industry, sugarcane industry, OSH, OSH, OHS, OHSMS, H&S, occupational health and safety management, workplace safety, hazards, accidents, and incidents. The data source for this review was the Scopus database.

Inclusion and Exclusion Criteria

The Boolean logic employed includes (AND, OR, AND NOT) to exclude irrelevant studies and to ensure specificity. An example of the search is:

TITLE-ABS-KEY ((sugarcane OR "Sugar Cane" OR "Sugar industry" OR "Sugarcane industry")) AND (("Process Safety" OR osh OR "OHS" OR "OHSMS" OR "H&S" OR "Occupational health and safety management" OR "Workplace safety" OR safety OR hazards OR accidents OR incidents OR precursor)) AND (("Developing countries" OR "Low- and middle-income countries" OR lmic OR african OR "Poor countries" OR sudan)) AND NOT "Genetic engineering"

The search resulted in a large number of studies (n= 614), however, applying the inclusion and exclusion criteria listed in table 1 reduced the number to (n=21). The 21 studies included are original peer-reviewed studies published in English between 2000 and 2023.

Table 2: Inclusion and exclusion criteria

Criteria	Description
Exclusion	
EXC1	The document is an editorial, letter, or report.
EXC2	The main body of text for the article is not written in English.
EXC3	The full text of the document is not accessible.
EXC4	The document provides no information on sugarcane cultivation safety.
EXC5	The document provides no information on sugarcane processing safety
EXC6	Published before 2000
Inclusion	
INC1	The document is a peer-reviewed journal article, original research, or review paper in English published between 2000 and 2023 or in press written.
INC2	The document provides information on sugarcane cultivation health and safety.
INC3	The document provides information on sugarcane processing health and safety
INC4	The document is medically based but focuses on sugarcane workers' occupational health
INC5	The document is climate or environmental-based but focuses on sugarcane workers' occupational health.

Quality Appraisal

The quality of the studies included in this systematic review was appraised using a generic tool used for assessing numerous intervention study designs introduced by the Effective Public Health Practice Project Canada (EPHPP) [21]. The author assessed the 21 studies in an unblinded, standardized manner, and monitored the quality of the assessment. However, none of the studies were excluded because of their quality assessments [22] due to the lack of data on the effects of sugarcane cultivation and processing on workers' physical and psychological health and safety (Figure 2): presents a PRISMA flow diagram depicting the application of eligibility criteria, the process of identification and screening, and the reasons for inclusion and exclusion. The studies included must focus on or partially address the impact of sugarcane cultivation or processing on workers.

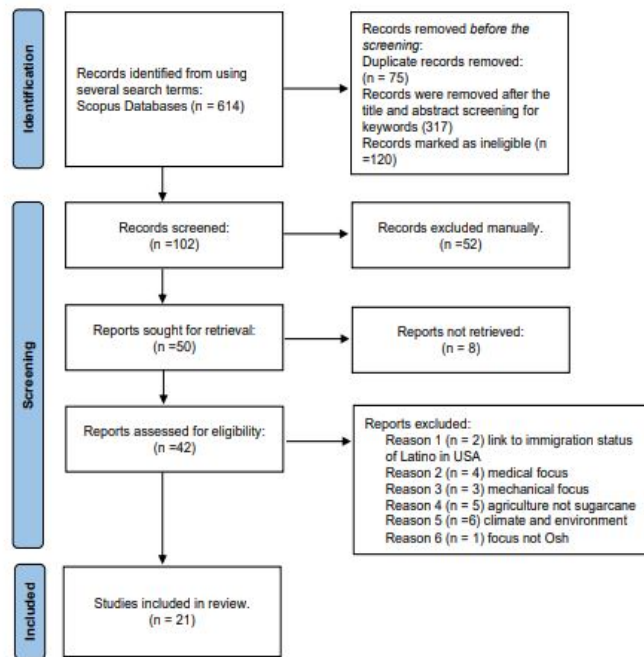


Figure 2: PRISMA flow diagram

Results

This systematic literature review included (n=21) peer-reviewed studies following the PRISMA selection process and the inclusion-exclusion criteria detailed above. The first identification process identified (n= 614) studies after which several screening steps were carried out and duplicates and illegible articles, reports, and conference proceedings were removed. 42 articles remained for full article reading resulting in the (n=21) articles included in the review.

A descriptive analysis of the study designs utilized, the sources used, the countries the studies were conducted in, and the Agro-industrial stages they were concentrated on was done to provide a summary of the included studies. When the methodological approach of the publications was examined (Figure 3), it was shown that 38% of the articles used a quantitative approach technique. This finding might point to the necessity of other research designs including mixed-method, qualitative and medical examination approach to have a more understanding of the causes of accidents in the sugarcane industry.

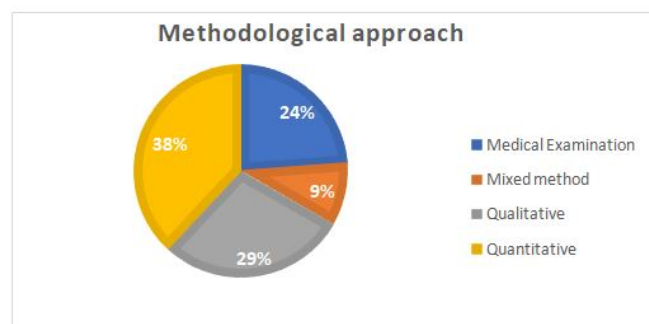


Figure 3: Analysis of Methodological approach

Deploying different research methods is believed to strengthen the research's credibility and help to highlight any discrepancies between qualitative and quantitative findings.

Furthermore, the selected articles were analysed to determine the agro-industrial stage that possess high impact on workers' physi-

cal and psychological health and safety see (Figure 4): it was noted that the most hazardous stage of sugarcane agro- industrial processing is the cultivation phase, where 52% of the risks occur. Some risks that happened during both rounds of stages come last after processing.

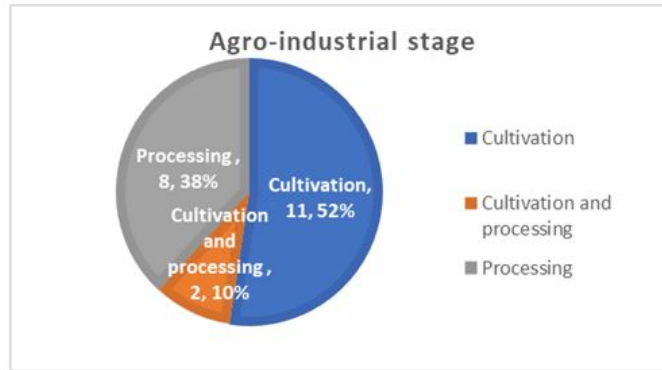


Figure 4: Analysis of hazards in Agro-industrial stages

Around half of the 21 studies were conducted in South American countries, with three studies undertaken in Brazil. There were two studies from Costa Rica, Nicaragua, and Ethiopia. None the less, no studies on health and safety in sugarcane cultivation or processing in Sudan were found despite using search terms like Africa, LMIC, developing countries, or Sudan. Obviously, there is a paucity of research in this area in Sudan. See Figure 5

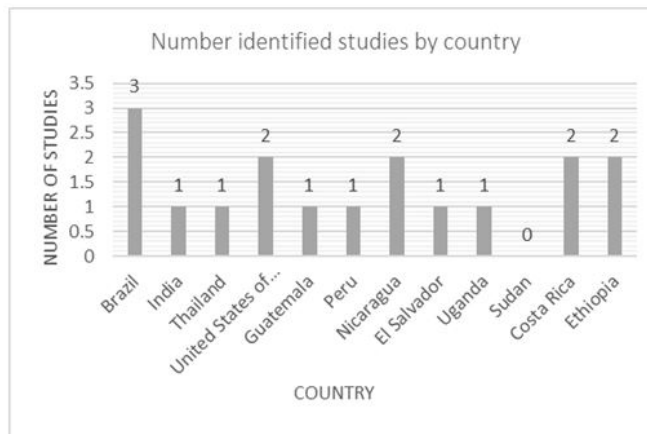


Figure 5: Distribution of studies by country

Only 2 of the 21 publications in this study addressed sugarcane production's growing and processing phases. Most studies focused on sugarcane cultivation, addressing the impact of heat and nocturnal burning on farmers' kidneys and respiratory systems. Some of the studies included were of medical or environmental background focusing on occupational health.

Evidence of Injury and Illness

Manual Cane-Cutting

The literature on sugarcane cultivation reveals a range of hazards associated with working in sugarcane fields. Despite technological advances in mechanised harvesting, sugarcane is still harvested manually in several countries around the globe [23]. Since it requires the performance of vigorous and repetitive movements with a machete the manual cane-cutting process creates a high physical load on the cutter [23,24].

Nocturnal Burning

Many studies have identified a negative effect of pre-harvest burning on human health that relates to lung function and the respiratory system. Nocturnal burning is carried out to facilitate manual cutting and to eliminate the incidence of accidents by poisonous animals during the harvest season. This practice releases a considerable percentage of gaseous and particulate matter (PM) into the environment, which is consequently inhaled by workers [24]. The inhalation of particulate matter released while cutting burned cane can affect the upper and lower airways, causing symptoms of respiratory diseases and lung function impairment in workers [23]. Furthermore, Prado et al. (2012) documented the exposure of workers and the residents around sugarcane farms to the smoke from burning the sugarcane throughout the nearly 8-month harvest period. Le Blond et al. (2010) argued that workers exposed to the ash formed during sugarcane burning are potentially at risk of developing respiratory and related problems Le Blond et al. (2010). These scholars added that the temperatures during the pre-harvest burning of sugarcane are within the range required to form crystalline silica. Hence, workers are exposed to a potential risk of silicosis and other silica-induced diseases, the symptoms of which may take years to manifest Le Blond et al. (2010).

For example, in Brazil it was found that the burning of sugarcane fields was particularly harmful to plantation workers, exposing them to more significant risks of lung cancer [1]. Burnt sugarcane harvesting was also linked to acute renal dysfunction in previously healthy workers. This was associated with dehydration, systemic inflammation, oxidative stress, and rhabdomyolysis [25]. In this view, the above-mentioned studies confirm that burning sugarcane negatively impacts workers' respiratory systems and kidneys. Although some workers put clothes on their faces to avoid respiratory discomfort, there is no scientific evidence that such a technique prevents inhaling pollutants from burning [24].

Disease and Epidemics

Sugarcane cutting is repetitive high-intensity work where workers spend over half their workday at or above 50% of their maximum heart rate. Heat exposure, strenuous exercise, and dehydration pose a significant challenge to the cardiovascular system and oxygen transport to exercising muscles and vital organs, such as the kidney [26]. Sugarcane harvesting has been associated with an epidemic of chronic kidney disease in Central America mainly affecting previously healthy young workers [25]. For instance, heat distress has been postulated as a causal factor of Central America's chronic kidney disease epidemic [27]. [28] provided evidence for an association between physically demanding job tasks and kidney injury in a population exposed to high environmental heat levels [28] Several studies have shown that muscles release myoglobin under these conditions, which can produce acute kidney damage, especially in combination with dehydration. In addition, systems regulating water and electrolyte balance become overwhelmed, resulting in urine acidification, concentration, and uricosuria, leading to chronic kidney disease [26,29,30].

Also, [23] underlined the impact of harvesting activities on the cardiovascular system of sugarcane cutters. The sugar cane cutters showed evidence of increased blood pressure, cardiovascular load, changes in the autonomic nervous system, and changes in blood coagulation ability during the harvest compared to the pre-harvest [23].

In addition, there has been some attention given to several issues including linking sugarcane production to malaria, Ghaghas' disease, and schistosomiasis increase in HIV infection [1]. In this context, the literature presented provides clear evidence that there

are several life-threatening diseases and epidemics associated with sugarcane growing in Africa and South American countries.

Table 3: summary of studies included in the reviews

No.	Author/s	Journal	Year	Methods	Location	Contributions	Agro-industrial stage
1	(Pawar et al., 2019)	Biomedical Research	2019	Questionnaire	India	Duration for development of WRMDs within 1-5 years	Processing
2	(Hess et al., 2016)	Global Environmental Change	2016	SLR	Sub-Saharan Africa	The temperatures during pre-harvest burning of sugarcane are within the range required for the formation of crystalline silica	Cultivation and processing
3	(Abuswer et al., 2013)	Journal of Loss Prevention in the Process Industries	2013	Case study	USA	Develop a QRMF that reduces the risk of dust/hybrid mixtures explosion	Processing
4	(Santos et al., 2015)	Kidney International	2014	UBS	Brazil	The burnt sugarcane harvesting caused an acute and significant impact on acute kidney dysfunction.	Cultivation
5	(Trevisan et al., 2019)	Brazilian Journal of Otorhinolaryngology	2018	Questionnaire	Brazil	Burnt sugarcane harvesting affects the rhinitis symptoms and inflammatory markers in sugarcane workers.	Cultivation
6	(Prado et al., 2012)	Science of The Total Environment	2012	Interviews, BT Questionnaire, ME	Brazil	Biomass burning increases the prevalence of respiratory symptoms among sugarcane workers.	Cultivation

7	(Sakunkoo et al., 2011)	Asia Pacific Journal of Public Health	2011	DSA	Thailand	Workers in sugar plants are likely to be exposed to high concentrations of inhalable dust and are at risk of developing asthma and bronchitis.	Processing
8	(Le Blond et al., 2010)	Journal of Environmental Monitoring	2010	Experiment	South American countries	The temperatures during pre-harvest burning of sugarcane are within the range required for the formation of crystalline silica	Cultivation and processing
9	(Crowe et al., 2013)	American Journal of Industrial Medicine	2013	Observation and guidelines	Costa Rica	Sugarcane harvesters are at risk for heat stress for most of the work shift.	Cultivation
10	(Levi et al., 2018)	Med Lav	2018	LR	Review	The relationship between high workplace heat levels and health effects in workers, even in younger age groups	Cultivation
11	(Wegman et al., 2018)	Scandinavian Journal of Work, Environment & Health	2018	UBS	El Salvador	link strenuous labour, heat stress and kidney damage among sugarcane workers	Cultivation
12	(Bonsa et al., 2019)	Journal of Public Health	2018	Questionnaire	Ethiopia	Lack of PPE, safety audits and labour inspections are predictors of occupational exposure to bagasse dust.	Processing

13	(Taffere et al., 2020)	Journal of Public Health	2019	Questionnaire and HRCL	Ethiopia	This study revealed that the levels of heat and noise exposure measured were found to be higher than the occupational exposure limit	Processing
14	(Hansson et al., 2021)	Occupational and Environmental Medicine	2021	UBS	Nicaragua	In sugarcane workers kidney injury among heat-stressed workers and progressive kidney disease is likely.	Cultivation
15	(Bazo-Alvarez et al., 2022)	BMJ Open	2022	Questionnaire	Peru	Mental disorders among Sugarcane farmers have higher mental disorder symptoms than their non-farmer peers because of the heavy workload and more working hours per day.	Cultivation
16	(Aremu et al., 2022).	Journal of Musculoskeletal Disorders and Treatment	2022	Survey	Uganda	Musculoskeletal disorders among sugar factory workers are high due to ergonomic risk exposure	Processing
17	(Tribble et al., 2016)	Archives of Environmental & Occupational Health	2015	Questionnaire	North Carolina	Depression and precariousness are correlates of musculoskeletal disorders and pain	Cultivation

18	(Stumpf et al., 2020)	International Journal of Audiology	2019	DEoED	Guatemala	Need to perform personal noise dosimetry approaches to quantify specific job/worker exposures due more precisely to the integration of time with sound level	Processing
19	(Glaser et al., 2020)	Occupational and Environmental Medicine	2020	Questionnaire an US	Nicaragua	Improving work conditions and close monitoring for more extended periods is key to evaluating the full impact of reduced heat stress on kidney health	Cultivation
20	(Gascon et al., 2012)	Occupational and Environmental Medicine	2012	Questionnaire	Costa Rica	In this sugar cane refinery, the differences in workers' ventilatory lung function before the harvesting season are unlikely to be explained by bagasse exposure	Processing
21	(Leite et al., 2018)	Revista de Saúde Pública	2019	Critical review	Review	Work on the manual cutting of sugarcane, especially of burned sugarcane, exposes workers to various risks, with different health impacts.	Cultivation

Physical Work and Heat Distress

It is established that exposure to extreme heat can cause adverse health effects and decreased productivity. In sugarcane production, heat stress is a significant concern [31]. Workers involved in moderate- or high-intensity activities in hot locations during the hot season are prone to heat-related health problems.

Physical work activities create intra-body heat production, which adds to the environmental heat stress. A growing body of scientific evidence indicates that exposure to excessively high heat levels already results in excess morbidity and mortality in the general population, particularly among the elderly [31].

Several studies have researched the impact of heat stress and dehydration on sugarcane cutters. For example, [26] reported that sugarcane cutters spent almost 80% of their working hours in conditions above 26°C exceeding permissible heat exposure threshold limits for continuous heavy labour for most of their workday [26]. In addition, [27] demonstrated that sugarcane harvesters work strenuously in harsh climatic conditions and are at risk for heat stress for most work shifts [27]. [23] reported that sugarcane workers experienced symptoms associated with exposure to heat or dehydration like headache, tachycardia, cramps, fever, nausea, dizziness, hand or foot edema, and dysuria at least once a week when evaluated [23].

The literature reflects that great attention is given to the impact of heat on sugarcane workers given the nature of sugarcane labor activities, long days, and seasons. Because of that, [27] recommended immediate action to reduce heat exposure and health risks. The scholars suggested further research on the long-term health effects of chronic exposure to extreme heat [27].

Respiratory, Allergy, and Eye Problems

After juice extraction, bagasse (sugar cane fibers), is used to generate energy for the sugar processing plant to start the factory for the next season, to produce paper and disposable food containers, or as food for cattle. Worth noting, this bagasse is often contaminated with high levels of bacteria and moulds [32]. Unfortunately, workers are exposed to high level of bagasse contamination during the harvest period [32].

Due to this fact, the literature related to sugarcane production associates the sugarcane industry with several health and safety hazards. For example, [32] associated dust exposure and microbiological agents with respiratory, allergy and eye problems. Their study in a Costa Rica sugarcane refinery found that some departments' dust levels were relatively high during the harvesting season, while endotoxin and mould levels were around background levels. They found that, during the harvesting season, the prevalence of wheeze and eye problems almost doubled in workers exposed to bagasse and other types of dust. They also found that shortness of breath and rhinitis increased only in bagasse-exposed workers. Years of working at the refinery were positively associated with wheezing and shortness of breath, suggesting long-term health harm [32]. Another example is [33] who found that the measured levels of bagasse dust exposure were higher than the permissible limit in Metehara Sugarcane Factory, Ethiopia. They noted that the occupational exposure to bagasse dust associated with the sugarcane manufacturing process poses a potential hazard to workers' health, safety, and organisational productivity [33].

Moreover, [2] found that workers in sugar plants are likely to be exposed to high concentrations of inhalable dust, from bagasse storage and dumping sites, and are at risk of developing asthma and bronchitis. They also linked high levels of respirable bagasse dust to bagasse-specific respiratory illnesses, such as bagassosis and extrinsic allergic alveolitis [2].

There is a convergence among various studies on the impact of bagasse on sugarcane workers during sugarcane cultivation and processing. [33] emphasised the significance of considering the key determinant factors, such as the absence of job rotation practices, ventilation systems, safety audits, labour inspections, personal protective equipment, and job dissatisfaction, when implementing occupational health and safety measures to protect workers' health [33].

Exceeding the Noise Exposure Limits

In their study of a Guatemalan sugar cane mill, [34] found that most of the workers demonstrated levels of exposure to hazardous occupational noise exceeding the NIOSH recommended exposure limit of 100% noise dose (85 dBA TWA) and the Guatemalan permissible exposure limit workers [34].

They also noted that job duties like cleaning inside an evaporator might produce extreme exposure. Despite working seasonally, they argued, these workers are over-exposed and that working 6 days a week shortens the potential auditory recovery time compared to the traditional 8-hours 5 day-a-week schedule. Another study in the Metehara sugarcane factory in Ethiopia reported that the measured noise exposure levels exceeded the accepted occupational exposure limit exerting a potential hazard to workers' health and safety and organisational productivity [35].

[34] proposed a global hearing conservation programmer method to execute personal noise dosimetry approaches to estimate specific job/worker exposures more precisely due to the integration of time with sound intensity [34].

Work-Related Musculoskeletal Disorders (WRMSD)

Musculoskeletal disorders (MSDs) cases are commonly reported among Latino manual workers across all industries. Manual workers' musculoskeletal pain is associated with a poor work safety climate. Work safety climate refers to worker perceptions about how their employers prioritise workplace safety over production. Work safety climate is one component of work organisation, which includes the work timeframe, the physical and psychological demands of work, the control that workers have, and the style of supervision and support workers experience [36].

Occupational health hazards are seen in sugar factories where 87.1% of workers have musculoskeletal disorders due to bad working conditions, lousy lifting positions, and lifting heavy loads [37]. Even low back pain increases with the increased durations of work, also such increased durations, lead to other types of pain such as shoulder pain, elbow pain, upper back pain, hip pain, knee pain, and ankle pain [37].

In the same context, [38] discussed that work-related musculoskeletal disorders (WRMSD) among workers in two sugar factories in Uganda is a neglected area in research. Despite the paucity of research, it was found that MSDs cases are relatively common among sugar factory workers [38].

Furthermore, Lower back pain cases were the most reported anatomical areas for Musculoskeletal Disorder (MSDs) cases among the workers in almost all the units of the sugar factories. The prevalence of lower back pain among sugarcane workers was associated with working conditions, manual handling, prolonged twisting, and repetitive movements. However, workers in the mechanized factory were also prone to developing MSDs but to a lesser extent than workers in the non-mechanized factory [38].

The findings of the reviewed studies confirmed the negative impact of sugarcane cultivation and processing on the health and safety of workers. In addition to that, other studies highlighted different sources of risk such as explosions, fires, and psychological disorders.

Explosions and Fires in Sugarcane Factories

[39] noted that icing and granulated sugar dust is identified as hazardous materials in sugar refineries [39]. In 2008 the Imperial Sugar refinery, one of the largest sugar refineries and packaging complexes in the United States, exploded causing a fire and the destruction of the refinery and killing 14 workers and injuring 36. The explosion was caused when an unknown ignition source inside the enclosed conveyor belts contacted an explosible concentration of airborne dust in the packing building [39].

Psychological Disorders and Workers' well-Being

Sugarcane farmers have higher mental disorder symptoms than their non-farmer peers. A heavy workload and daily working hours are independently associated with more mental disorder symptoms. Manual cane cutting is known to be particularly difficult, with some cutters in the past being physically abused [40]. In addition, harvesting is performed under high climatic temperatures and low humidity, which causes adverse effects such as physical and psychological stress and an increase in respiratory effort

[24].

Musculoskeletal disorders are heavily associated with the mental health and work organization [36]. related depression, work stress, work safety climate, and precariousness to musculoskeletal pain for Latino farm workers and nonfarm-worker manual labourers. Scholars also found that depression and precariousness correlate with musculoskeletal disorders and pain among migrant and immigrant workers [36].

Hence, the literature findings highlight the importance of including mental health within occupational programmers and early interventions tailored to sugarcane industrial mill workers [14]. Whilst working conditions of employees vary tremendously, still, manual cane cutting is known to be particularly arduous, with some cutters in the past being physically abused [1].

Socioeconomic Factors

Sugarcane workers are hired temporarily for seasonal employment on short-term contracts. In such cases, employers are relieved of their obligation to offer benefits such as pension contributions, health and social services, and employment insurance. In such situations, the challenges of establishing and maintaining representation through labour unions dramatically increase [1].

Health issues in sugar factories include the physical and ergonomic stresses associated with cane cutting over extended periods and the risk of disease from the cramped and poor quality of housing provided to plantation workers [1]. Payment per production is an additional risk factor, as it induces a longer work rate to guarantee a slightly better wage and a greater possibility of hiring in subsequent harvests [23].

Discussion

The primary purpose of this systematic review was to assess the literature coverage of the significant occupational health and safety issues that sugarcane workers face during the cultivation and processing of sugarcane. To the authors' knowledge, no comprehensive study has examined the sugarcane agro-industrial sector's occupational health and safety nor its process safety during the two phases of its production.

Given the dearth of evidence on occupational health and safety globally and in Sudan, this systematic review fills an essential gap in the literature. The findings of this study are of value to workers, employers, OHS practitioners, and policymakers who are interested in knowing the impact of sugarcane activities on the health, safety, and well-being of workers. The findings are also of value to OHS researchers, who might seek to fill some of the gaps in the literature on the impact of health and safety management on the economics of individuals and countries.

Although the focus of this study was on occupational health and safety, several pieces of evidence were found focusing on the impact of sugarcane cultivation and processing on the health of workers and medical investigations.

There is a growing body of evidence that identified a range of hazards in sugarcane farms and factories, including exposure to harmful chemicals, physical and ergonomic hazards, and heat stress. Workers in the industry are also at risk of musculoskeletal disorders, respiratory problems, and skin diseases. These hazards can lead to serious injuries and fatalities and can also have long-term health effects. In addition, there is a consensus among the studies reviewed that manual cutting of sugarcane and the burning process pose a tremendous risk to workers during the sugarcane harvesting phase. These two sequential processes expose workers to several risks responsible for health problems including respiratory, renal, cardiovascular, and dermatological [23].

It was found that the studies reviewed relied on different research designs including quantitative and qualitative and few studies used mixed methods. Around nine studies used questionnaires or combined questionnaires with interviews. Hence, some level of bias might have set in during the filling of the question naire. For example, respondents might not have reported all musculoskele-

tal and respiratory symptoms they are experiencing [23].

Several studies agreed on the provision of Personal Protective Equipment (PPE), regular safety training, establishment of a safety committee, access to shade, and using ergonomic tools as a measure to manage health and safety in sugarcane cultivation and processing. The measures suggested are proven to lead to a significant reduction in the number of accidents and injuries in sugarcane factories. This finding is consistent with that of Debela & Taferi (2018) who reported that the provision of appropriate PPE, safety training, adequate management support, and workers' positive attitudes towards safety measures were diviners to sufficient occupational health and safety practices. In the same vein, Glaser et al. (2020) reasoned that heat stress management, including providing potable water, rest and shade will reduce the likelihood of sugarcane workers developing kidney cancer.

In the context of Sudan, while progress in the knowledge and expertise accumulated over its 50 years of history in Sudan's sugar industry [7] the management of occupational health and safety or process safety within the sugarcane industry was not evident. Given Sudan's current economic and political instability, cost pressure, existing plant ageing, and new technology [17] process safety management is highly recommended.

The primary focus of process safety is the prevention and mitigation of incidents that arise from the realisation of process hazards, including fire, explosion, and the release of toxic materials [41,17] argued that process safety incidents could lead to catastrophic consequences resulting in multiple injuries and fatalities, and substantial economic, property, and environmental damage [17]. This study highlights the need to manage process and occupational safety in the sugarcane industry. However, the sugar refining is a highly energy-intensive process, it was noted that process safety in the sugarcane industry is not identified in any of the identified literature.

Limitation of the Study

The present study has a few limitations that should be acknowledged, including that Scopus is the only database consulted and that there were limited number of papers on the topic were found in Scopus. Another limitation is that only studies published in English were included, that means information in studies published in other languages would have been a good contribution to the current study given the dearth of studies in the topic.

Conclusion

In conclusion, sugarcane cultivation and processing are hazardous procedures. Eventually, agricultural workers face numerous safety hazards daily. While progress has been made in understanding the root causes of agriculture-related accidents, more research is needed to fully understand the various factors that contribute to these accidents and to develop effective strategies to prevent them. That's why it is essential to manage both process and occupational safety in the sugarcane industry.

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