

Research Article

A Preliminary Study on Accident Analysis of Portable Timber Sawmills Used in Mazamba Forest Plantation in Northern Malawi

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This study investigated the main causes of accidents, levels of injuries, and mitigation measures to wood processing accidents. Structured interviews were conducted on 45 respondents drawn from various portable sawmills. The Chi square test showed that there were highly significant differences on frequency distribution of causes of sawmill accidents. However, a principal component analysis revealed that accidents were mainly caused by inappropriate equipment setup or operation and harsh weather conditions. Secondly, results showed that the frequency distribution of responses on levels of accidents was highly significantly different among the respondents. Near-misses accounted for most of responses (55.6%). This is because near-misses are precursors to secondary accidents. Furthermore, the results showed highly significant differences on the frequency distribution of various mitigation measures available. Use of personal protective equipment and provision of special training were highly appraised. Forest workers need occupation safety and health and ergonomic knowledge before engaging in wood processing.

1. Introduction

Wood processing industries are regarded as high health and safety risk occupations in many parts of the world [1–3]. Over 2 million people in the world are believed to be dying each year as a result of forest-related accidents [4]. Most of the accidents occur during tree felling, manual timber extraction (log rolling), and portable sawmilling operations. Heinrich [5] postulated that, for every 300 near-misses, there are 29 injuries with a probability that one of those injuries being fatal. Naturally, accidents are unplanned, unforeseen, and unwanted events of a random character [6–8] in the forest workplace.

Forests are inherently dangerous work environments [9–11] owing to their locations and nature of the operations that are involved. Forest operations usually take place under adverse working conditions such as on steep slopes, remote areas, and harsh weather conditions. Furthermore, forest workers are typically exposed to sharp, heavy, and high-speed machine moving parts as they execute their

operations. The tasks are generally physical and mentally demanding leading to body fatigue and musculoskeletal pains [12, 13]. Critical operational judgments ought to be made timeously and judiciously in order to enable translation of actions into sound safety responses in workplaces [14]. A study conducted in New Zealand reported that the forest sector registered the highest injury rates of which 30% of logging injuries occur during the felling task [15]. The Centre for Human Factors and Ergonomics [16] reported that sawmills account for at least 50% of all the injury claims in the wood processing industries followed by the pulp and ply-mills. In Italy, however, the plywood industry had been reported to be at least twice more accident prone than other sectoral manufacturing industries [17]. On the other hand, 25% of accidents in developing countries are caused by tree hang-ups [18]. In Tanzania, Silayo et al. [19] reported that at least 50% of the timber harvesting crews get involved in accidents in one way or another in the course of executing their operations. It is clear, therefore, from these reports that

both the forest and wood processing industries have high accident risks.

In northern Malawi, wood processing is mostly done by small-scale but many sawmills. Operation of these mills is mostly dominated by a work force that does not have formal training. Workers pass on skills to one another right on job. Unfortunately, these operational skills nebulously carry occupational safety skills. Poor operational skills include, but not limited to, poor setting up of machines on the ground, playing unsafe acts, and working in unsafe conditions [20]. Sawmills ought to be set on well-levelled grounds or on solid concrete foundations to avoid machine vibrations or even falling off. Unsafe acts constitute unacceptable behaviours of operators (such as horseplay, repairing machines while in motion, and working while drunk) at work. This is a cause for concern as productive youths continually get involved in workplace accidents in Viphya (Mr. S. Nyandeni, 2018, Forester, Viphya Forest Plantations, Malawi, pers. comm.).

Occupational health and safety has a significant effect on the social and economic thrust in the forest sector and society [21, 22]. Accidents have the potential to reduce productivity [19] and degrade corporate image of the forest sector [23] owing to the fact that occupational safety and health is a human right for every person. Papadopoulos et al. [24] stressed that occupational safety management and the associated decisions must enable protection of the workforce at all costs. This withstanding, such interventions become difficult to execute in the absence of comprehensive accident databases in workplaces [25, 26]. Anecdotal evidence shows that many forest workers are highly involved in occupational accidents on the Viphya forest plantation sawmills. Unfortunately, such information has not been investigated to provide insights that can inform strategic and focused decisions on forest accident prevention research. Therefore, the objectives of this study were to determine the main causes of accidents, assess the levels of injuries, and determine the mitigation measures of accidents in portable saw milling operations in northern Malawi.

2. Methodology

2.1. Description of the Study Site. The study was conducted at Mazamba forest station on the Viphya forest plantations between 2016 and 2018. Mazamba forest is located in Nkhata Bay district in northern Malawi. It shares its borders with Champhoyo forest to the south, Nthungwa forest to the west, and Lusangazi forest to the north (Figure 1). The forest covers 6,450 hectares composed of tropical exotic trees species such as *Pinus patula*, *P. oorcapa*, *P. taeda*, and *Eucalyptus grandis*. Generally, Mazamba receives $>1000 \text{ mm}\cdot\text{yr}^{-1}$ on average of rainfall in summer but it becomes cooler and misty in winter months. Mazamba was purposively selected because it was the only active small-scale timber harvesting and wood processing site on the Viphya forest plantations during the time of the study. During the time of study, forest and wood processing accidents occurred more frequently at Mazamba. There were four active small industrial sites where portable sawmilling operations were taking place, namely, Cashgate 1, Cashgate

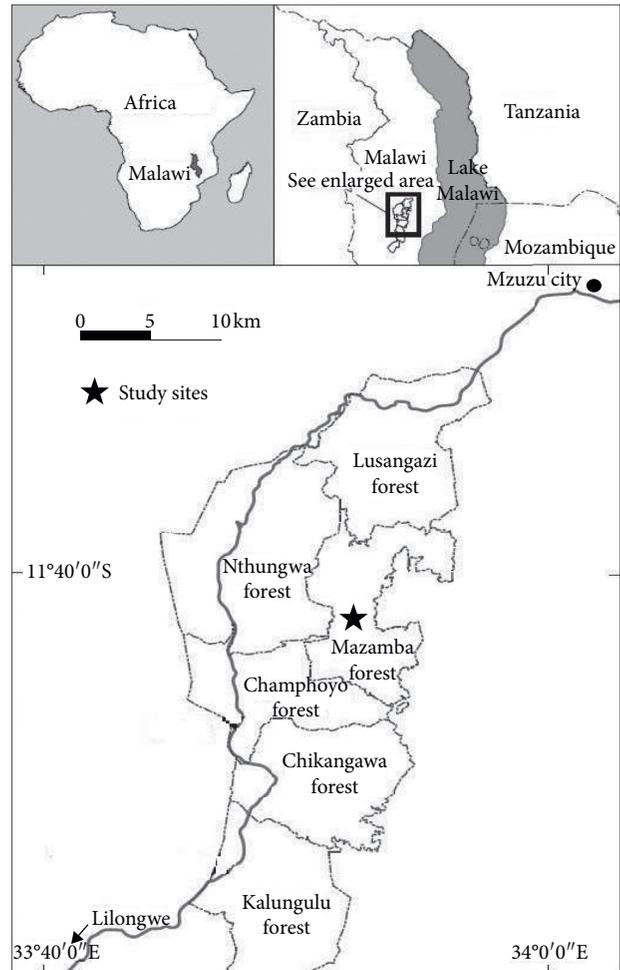


FIGURE 1: Map showing location of Mazamba forest station, adapted from [27].

2, Broken, and Bodobodo. These sites were distributed across Mazamba forest plantation sawing area.

2.2. Description of the Respondents. Due to the nature of work, the subject respondents involved in this study were only males. Their ages ranged from 19 to 49 years with the majority falling in the age class of 30–49 years. Only one respondent was below the age of 20 years. About 66% of the subjects had attended primary school education while the remaining percentage had at most attended secondary education. Their operational skills were variable. A few were experienced in timber harvesting and mobile sawmilling while the majority of them were unexperienced. Amec mobile mills were the most commonly used machines in sawmilling. Other timber producing (sawing) machines were woodmizers, chainsaws, and manually operated pitsaws.

2.3. Research Design and Sample Size. The study used a purposive sampling technique for saw millers and random sampling for forest community members. This involved selection of a sample from a population of workers involved

in portable saw milling operations. The population comprised portable mill operators, assistants, log rollers, community members, and key informants. A sample size of 45 workers was drawn from a population of 130 workers. The selection of a sample size was largely based on experience and willingness to participate in the study. Workers with less than one-year experience were excluded in the study as they did not comprehensively possess institutional memory of wood processing accident activities. Nevertheless, this sample size was adequate to satisfy statistical requirements based on the central limit theory [28]. Machines involved were woodmizers, Amec, chainsaws, and pitsaws. A woodmizer uses a bandsaw to cut logs while an Amec cuts by using a circular saw blade. Both machines are powered by diesel engines. Chainsaws are motor-manual machines that are used to rip saw the logs while pitsaw blades are manually operated by two operators to do the same job.

2.4. Data Collection Methods and Variables. Data collection was done using a structured questionnaire administered through personal interviews. The questionnaire was designed to obtain information on the following key variables: main causes of accidents; severity of injuries; and appropriate mitigation measures of accidents. Pretesting of questionnaire was done prior to commencement of the exercise to ensure adaptability, relevance, and applicability of methods, questions, time, and approach in the study area.

2.5. Data Analysis. Data were organised and analysed using Statistical Package for the Social Sciences (SPSS) Version 16.0 for Windows. Percentage relative frequencies of respondents were determined. Chi-square tests were used to determine statistically significant ($P < 0.050$) differences among response frequencies in relation to independent variables in the study. Principal component analyses (PCA) on a nominal data scale were used to extract main components on causes and mitigation measures of accidents at eigenvalue = 1.

3. Results

3.1. Main Causes of Accidents in Portable Saw Mills. The following causes of accidents were analysed: (1) inappropriate machine setup, (2) inadequate skills to operate the machine, (3) harsh weather conditions, (4) poor position of the sawmill operator, (5) drug consumption, (6) fatigue, and (7) weak supporting poles and ropes. The chi-square test (Table 1) showed that there were highly significant ($\chi^2(6, N=5) = 25.78, P < 0.001$) differences on frequency distribution of responses to the causes of accidents in portable saw mills. Some 37.8% of the respondents indicated that inappropriate machine setup was the main cause of accidents. About eighteen percent of the responses indicated that inadequate operational skills were the main cause of accidents. At least 4.4% of the respondents indicated that accidents were mainly caused by fatigue and weak supporting poles to the machines. Results of the PCA showed that inappropriate machine setup, inadequate skills to operate machines, harsh

weather conditions, and poor position of the sawmill operator had an eigenvalue >1 , accounting for about 71.7% of cumulative variance. Inappropriate machine setup alone contributed about 20.3% of the total variance.

3.2. Level of Accidents in Portable Sawmills. Near-miss, minor, major, and fatal constituted the levels of accidents. The chi-square test on frequency distribution of responses on accident level showed that differences were highly significant, $\chi^2(3, N=45) = 22.53, P < 0.001$, in portable sawmills (Table 2). Respondents (55.6%) indicated that near-miss was the most frequently encountered accident. Twenty percent of the respondents indicated that they were involved in or witnessed minor accidents. At least 8.9% of the respondents reported to have witnessed fatal accidents in portable sawmills.

3.3. Preventive Measures of Portable Sawmill Accidents. The following variables were analysed for candidacy to preventive measures for accidents (Table 3): (1) using personal protective gear, (2) need for special training, (3) using ergonomically designed chainsaws, and (4) concentration while working. A chi-square test of independence showed that differences among these variables were highly significant $\chi^2(3, N=45) = 134.02, P < 0.001$. The use of personal protective gear accounted for 31.1% of the responses on accident prevention. Need for special training of workers to mitigate portable sawmill accidents had the highest (57.8%) number of respondents. About 2% of the respondents indicated that accidents could be prevented by “concentrating” while working. A principal component analysis revealed that use of personal protective gear and provision of special training were the overarching variables (eigenvalue >1) for accident prevention among forest workers.

4. Discussion

4.1. Main Causes of Accidents. The highly significant ($P < 0.001$) differences of the main causes of accidents (Table 1) are related to personal and environmental factors. Personal factors entail the ability of workers to be able to appropriately execute tasks with minimal accident risks [29], while environmental factors relate to conditions in which the work is taking place. Thus, accidents were mainly caused by the inability to appropriately set up or operate machines and harsh weather conditions (Eigenvalue >1). Poorly setup machines yield unexpected motions and vibrations which are reason enough to cause occupational accidents. The cause for poor machine setup is partly attributed to difficult terrain (slope, ground roughness, and ground condition) in forest environments, poor technical condition of the machines (unbalanced telescopic leg lengths), and poor ground levelling techniques [30]. Furthermore, the influence of drug and/or alcohol consumption was also common among forest workers at Mazamba. Some workers believed that *Cannabis sativa* locally known as *chamba* smoking and/or alcohol consumption enhanced their productivity. On the contrary, literature [31–34] has discounted any assertions of improved

TABLE 1: Response frequencies and variance account on causes of accidents.

| Causes of accidents | No. of respondents (N=45) | Relative frequency of respondents (%) | Total % | Initial eigenvalues | | Extracted component |
|---------------------|---------------------------|---------------------------------------|---------|---------------------|--------------|---------------------|
| | | | | % of variance | Cumulative % | |
| 1 | 17 | 37.8 | 1.423 | 20.327 | 20.327 | * |
| 2 | 8 | 17.8 | 1.307 | 18.675 | 39.002 | * |
| 3 | 7 | 15.6 | 1.178 | 16.831 | 55.833 | * |
| 4 | 6 | 13.3 | 1.110 | 15.859 | 71.692 | * |
| 5 | 3 | 6.7 | 0.814 | 11.626 | 83.318 | |
| 6 | 2 | 4.4 | 0.735 | 10.497 | 93.816 | |
| 7 | 2 | 4.4 | 0.433 | 6.184 | 100.000 | |
| χ^2 | | 25.78 | | | | |
| df | | 6 | | | | |
| P | | <0.001 | | | | |

*Denotes extracted factors with eigenvalue >1.

TABLE 2: Responses on level of accidents encountered or witnessed.

| Level of accident | No. of respondents (N=45) | Relative frequency (%) |
|-------------------|---------------------------|------------------------|
| Near-miss | 25 | 55.6 |
| Minor | 9 | 20.0 |
| Major | 7 | 15.6 |
| Fatal | 4 | 8.9 |
| χ^2 | | 22.53 |
| df | | 3 |
| P | | <0.001 |

worker productivity. Instead, the substances abuse is said to slow down body coordination and mental ability, hence failure to set up and operate machines. The personal inefficiencies arise because most workers in Mazamba lack professional knowledge and training prior to timber harvesting and processing engagements. Similar studies on occupational safety [35–39] have acknowledged that personal factors are main causes of accidents.

Harsh weather was considered as an important environmental condition with regard to occupational safety for most workers. Exposure to precipitation while working induced slipperiness and visibility imprecision of objects. These were potential precursors to accident occurrences in the area. On the other hand, extreme temperatures created worker discomfort in the forest environment. Gnoni and Saleh [40] concur that unsafe conditions fail to meaningfully harness the safety value at workplace.

4.2. Levels of Accidents Incurred during Sawmilling. Accidents may exist as near-misses, minor, major and, in very extreme cases, fatalities. The ratio of near-miss:minor:major:fatal accidents is approximately 6:2:2:1 in Mazamba (Table 2). This implies that there are threefold near-misses in every minor or major accident with a probability of one fatal accident in timber processing operations. Although the trend on level of accidents mirrors a typical accident pyramid [5,40], the frequency rate in Mazamba is generally higher. Near-misses, interpreted as close-to-accident events, were more frequent for the unsafe acts and conditions that existed in a workplace. For instance, drug abuse and incorrect lifting of logs were common unsafe acts observed,

while noise levels and climatic factors were far below the specified threshold limits for worker exposure in Mazamba. In fact, most of the near-miss incidents go unnoticed by the workers.

Near-misses have far reaching consequences in as far as safety management is concerned [41]. It is cheaper to manage near-misses than higher-order accidents. Hence, a reduction of near-misses would simultaneously yield into a reduction of higher-order accidents for workers in the timber processing sector.

Meanwhile, the timber processing sector lacks comprehensive occupational accident analyses to enable accurate estimation of frequency and severity of accidents at workplace. Partly, this is attributed to practicing of temporal employment arrangements which do not provide amenable occupational social protection mechanisms [42]. Under temporal employment engagements, workers do not prioritise monitoring and evaluation (M&E) of accident occurrences at workplace. Inadequate M&E is retrogressive to development of future occupational safety and health interventions in line with the Occupational Safety, Health and Welfare Act [43]. Garland [20] reported similar findings in Zambia where occupational safety progress became almost impossible in forest operations.

While inadequate M&E appears to be a global concern on frequency and severity of accidents at workplace, accident rates are generally lower in developed countries such as Finland, Sweden, and Chile [44]. Observations revealed that small-scale wood processing mills, like those at Mazamba, are more prone to accident occurrence. There is need to reduce manual handling, provide and enforce use of protective equipment, and use ergonomically designed machines.

4.3. Mitigation Measures of Accidents. Portable sawmill accidents could be prevented by using ergonomically designed machines, concentration while working, using personal protective equipment (PPE), and engaging in specialised training (Table 3). The use of ergonomically designed machines could enhance a positive human-machine interaction through improvement of safety, comfort, and performance. Most machine moving parts including saws run unguarded.

TABLE 3: Frequency and variance accounted for by different preventive measures of accidents.

| Preventive measures | No. of respondents (N=45) | Relative frequency of respondents (%) | Total % | Initial eigenvalues | | Extracted component |
|---------------------|---------------------------|---------------------------------------|---------|---------------------|--------------|---------------------|
| | | | | % of variance | Cumulative % | |
| 1 | 26 | 57.8 | 1.703 | 42.567 | 42.567 | * |
| 2 | 14 | 31.1 | 1.288 | 32.205 | 74.772 | * |
| 3 | 4 | 8.9 | 0.970 | 24.256 | 99.026 | |
| 4 | 1 | 2.2 | 0.039 | 0.972 | 100.0 | |
| χ^2 | | 34.02 | | | | |
| df | | 3 | | | | |
| P | | <0.001 | | | | |

*Extracted factors with eigenvalue >1.

This is a high degree of safety hazard exposure of workers. According to Aneziris et al. [45], exposed machine moving parts are responsible for most of the accidents in sawmills. It is suggested that careful movements of workers and machine component guarding should be exercised as far as possible in the workplace in order to limit exposure to hazards.

Secondly, concentration while working is integral to prevention of risky incidences. It was highlighted that some workers lose their concentration at work because of participating in group or mobile phone conversations while working. This confirms the observation that workers did not have predetermined rest (break) times on which they could share social news and updates. It is important that workers have enough rest times and avoid fatigue and exhaustion to avoid loss of concentration according to Tsioras et al. [22, 46].

Personal protective equipment (PPE) and specialised training are probably the most important (Eigenvalue >1) accident mitigation measures. PPE helps to protect the worker at the "individual level." It also helps to reduce exposure duration of workers to potentially hazardous environments [47]. Most forest workers were observed to be using ordinary clothing rather than the specified protective gears. Part of the reason to this outcome was that some workers were not supplied with PPE by their employers. For those that had the protective gear, they argued that most protective equipment was either not user friendly or heavy to carry. Furthermore, unwillingness to use PPE was amplified by peer pressure among workers themselves. These arguments concur with the findings of [48] which indicated that effective use of personal protectors is largely governed by perceptions, misfit of PPE, and enforcement initiatives. When the use of PPE is not enforced, workers tend to ignore its use, and this makes their employers neglect provision of the gear. According to Klen [49], it may be important to further investigate perceptions of workers on their physical and psychological safety value in the workplace. However, Hull et al. [50], European Agency for Safety and Health at Work [7], and Laschi et al. [46] support evidence for safety value in use of PPE. Perhaps, introduction of local occupational safety and health structures in Mazamba could help to enforce safety issues.

The importance of worker training is overarching to mitigation of workplace accidents as demonstrated by the frequency of responses (37.8%) in Table 3. It was established that most of the workers enter into the timber processing profession without prior training. Learning is accumulated on-site through observation of their colleagues. This can be detrimental to personal and other people's safety as such workers lack basic occupational safety and health and ergonomic knowledge and skills. It was further established that workers lack formal training because of their educational backgrounds as the majority of whom are primary school leavers or secondary school dropouts. Hence, they are unable to effectively read instructions and engage in formal training.

Lastly, there are no customized training service programmes provided for frontline forest machine operators in Viphya. As such, customized training could be ideal for this group in order to mitigate accidents in Mazamba. Several researchers [51, 52] and Ghaffariyan [39] attest to the fact that trained workers are finitely less risky in being involved or causing accidents in the workplace.

5. Conclusions and Recommendations

Accidents in portable sawmills mostly arise from unsafe acts and conditions in the workplace. Machine operators lacked knowledge and skills to effectively set up and operate their machines. Drug and alcohol abuse were responsible for most forest occupational accidents with the majority of workers frequently encountering near-misses. Therefore, operator training that focuses on the removal of near-misses would translate in the reduction of higher-level accidents such as major accidents and fatalities. Accidents can further be mitigated by use of personal protectors and training prior to engaging in the profession.

It is recommended that accident analyses are comprehensively structured in future occupational safety and health interventions in timber harvesting and wood processing sectors. Future studies should unearth statistics on the types, magnitude, and severity of accidents in the forest workplace. It is important that local safety structures be instituted to enable near-miss management, safety training, ergonomics, and occupational safety and health enforcement. While participation of small-scale sawmilling activities is useful in

Viphyia, there is need to ensure adherence to best operating practices at all time in order to prevent occupational accidents.

Data Availability

This study was developed from newly collected and analysed data in partial fulfilment of the requirements of BSc degree qualification of and by Mr. Jameson T. T. Mzungu at Mzuzu University, Malawi. The data sets can be found at Mzuzu University in the Department of Forestry and Environmental Management.

Conflicts of Interest

The authors declare that no conflicts of interest exist in the funding and publication of this article.

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