Journal of Experimental Agriculture International

41(1): 1-10, 2019; Article no.JEAI.51846
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Risk Analysis in a Tropical Forest Wood Exploration and Processing System in Mato Grosso State, Brazil

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Authors' contributions

This work was carried out in collaboration among all authors. All authors performed the corrections and revised the drafts of the manuscript, as well as approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/v41i130391
Editor(s):
(1) Asist. Prof. Dr. Ismail Seven, Department of Plantal and Animal Production, Vocation School of Sivrice, University of Firat, 23119, Elazig, Turkey.
Reviewers:
(1) Martin Potgieter, University of Limpopo, South Africa.
(2) J. Dario Aristizabal-Ochoa, Universidad Nacional de Colombia, Colombia.
(3) Anil Kumar Koneti, Tirumala Engineering College, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/51846

Received 17 July 2019
Accepted 27 September 2019
Published 03 October 2019

Short Research Article

ABSTRACT

Forestry and logging activities in tropical regions are commonly carried out in inappropriate thermal conditions, due to the hot and humid climate, demanding from the worker high energy expenditure and physical effort. They often operate and handle machines and equipment that produce high levels of noise and vibration, and adopt postures that can be harmful to the body, given the constant lifting, handling and transport of loads above tolerable limits. The objective of this study was to evaluate the exposure of workers to risks in a rainforest harvesting and processing system in northern Mato Grosso State, Brazil. The study was conducted in two forest management areas and four processing industries. Occupational heat exposure was assessed and a qualitative analysis of noise and vibration was performed in the two study areas. Occupational exposure to heat was performed by determining the Wet Bulb Index and Globe Thermometer (IBUTG), while the

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qualitative analysis of noise and vibration was performed with the application of a Risk Analysis methodology. The results indicate that the values of the wet bulb index and globe thermometer (IBUTG), obtained every hour of the working day in the activities of the timber industry and wood processing, correspond to values above the tolerance limit, as standardized. The condition most likely to be harmful to health was found in the exposure to noise by workers in the wood processing industry, especially in operations related to the logging stages, where the risk was categorized as intolerable. With respect to exposure to vibration, the risk was higher in chainsaw operations in logging. In this case, it was possible to qualitatively analyze which occupational exposure limit (OEL) would be exceeded when the machine was in operation, representing risks to workers' health and safety. It is concluded that there is a need to adopt control measures, since the risk exposure levels were in a range that poses a risk to workers' health.

Keywords: Forest work; occupational diseases; sawmill.

1. INTRODUCTION

The Brazilian Amazon holds one of the largest tropical forests in the world and is a constant target of illegal deforestation. Therefore, in order to exploit the resources coming from these forests it is necessary that the area be regulated by sustainable forest management, which has its technical implementation standardized by Implementing Standard No. 1, of April 24, 2007 of the Brazilian Institute of Environment - IBAMA [1].

The timber use industry is becoming more discerning. The international market, for example, requires that the traded raw material be forest certified as a guarantee that the product is derived from a forest management area in which timber was legally harvested. There are several requirements to be met in the forest certification process, including those related to health and safety at work [2], which in Brazil are regulated by the Regulatory Standards of the Ministry of Labor in which states the minimum requirements for working conditions, hygiene and comfort of workers [3].

Forest and logging activities in tropical regions are commonly known to be performed in hazardous conditions, such as inappropriate thermal conditions due to hot and humid weather, operation and handling of machinery and equipment that produce high noise levels and vibration, as well as the adoption of improper postures given the constant lifting, handling and transportation of loads above the tolerable limits [4]. In considering that it is essential that workers' health and safety criteria are met for the forest certification process, and in view of the need for research aimed at assessing working conditions in the tropical forest timber sector, this study evaluated the occupational exposure of workers to heat and qualitatively analyzed the presence of noise and vibration in an exploration and processing system of tropical forest wood in the northern state of Mato Grosso, Brazil.

2. MATERIALS AND METHODS

2.1 Study Area and Description of Activities

Visits were initially conducted at random to several companies located in the northern region of Mato Grosso State, Brazil, where the purpose of this research was explained, in order to convince the entrepreneurs to collaborate with this study. Two forest management areas and four wood processing industries (sawmills) agreed to participate in this study.

The study was conducted from September to November 2017. The companies employed 57 workers during this period, 17 in forestry activities and 40 in the wood processing industries. Five forest operations and six main operations of the wood processing industries were selected for assessment of occupational heat exposure and for a qualitative analysis of noise and vibration at work.

2.2 Occupational Heat Exposure Assessment

The Wet Bulb Index and Globe Thermometer Index (IBUTG) was used to assess workers' exposure to heat, which provides results of heat assessment in the workplace, as established by Regulatory Standard - NR 15 [5]. In the forestry activity, an IBUTG thermometer (TGD400, Instrutherm) was installed in the log storage yard, as this is the place with the best representation of the thermal conditions of the management areas to be evaluated. In the wood processing industry, the appliance remained installed in the building where the wood sawing stages are performed, as this is the place where the vast majority of activities take place. With the thermometer on, IBUTG data were recorded and stored every five minutes to obtain an average value for each hour of the workday. The methodological procedures established by Occupational Hygiene Standard NHO-06 [6] were followed for collection. Thus, the heat values obtained by the IBUTG were compared to the tolerance limits established by Regulatory Standard NR-15 [5].

2.3 Qualitative Analysis of Physical Noise and Vibration Hazards

The physical risks of noise and vibration present in logging operations and in the wood processing industry were assessed through qualitative analysis using the Risk Analysis scale developed by Vale (2010) [7]. This analysis was based on three stages according to criteria established in Regulatory Standard NR-09, which deals with the Environmental Risk Prevention Program [8], which include (i) risk identification, (ii) risk analysis and (iii) risk assessment.

2.3.1 Risk identification

Risk identification was performed through systematic on-site observations of the typical working day. The operations were recorded using a camera, thus enabling to identify the source or sources which generate the considered physical risks.

2.3.2 Risk analysis

The risk analysis step aimed to understand:

2.3.2.1 Existing control measures

The existing management actions to control, reduce or eliminate the possible causes related to the identified risks were initially identified and recorded for the analysis of control measures. Thus, it was possible to identify if the existing control measures were being applied correctly or if there were failures in their use.

2.3.2.2 Worker exposure time

This analysis was performed according to the criteria set forth in Table 1. Due to the exposure duration to the environmental agent (risk), the value (index) was assigned from 1 to 5 (7).

Table 1. Criteria for estimating the exposure time to physical noise and vibration agents

Index	Duration per day (8 hours)
1	< 1 hour / 8 hour shift
2	1 to 2 hours / 8 hour shift
3	2 to 4 hours / 8 hour shift
4	4 to 7 hours / 8 hour shift
5	> 7 hours / 8 hour shift

2.3.2.3 Level or concentration of risk in the workplace

A qualitative estimate was performed to determine the level or concentration of exposure to the environmental agent, assigning the value (index) from 1 to 4 (Table 2).

The criteria for estimating the concentration or level of the environmental agent were based on the parameters established by the Occupational Hygiene Standards - OHS [9-11].

2.3.2.4 Exposure profile (frequency)

The exposure profile was obtained by multiplying the exposure time index by the concentration-level index. It was then categorized according to Table 3.

2.3.2.5 Occupational health effects

These were determined by categorization according to the severity of the damage as a result of the effects caused by the agent to the organism of the exposed persons (Table 4).

Table 2. Criteria to qualitatively estimate the concentration or level of noise and vibration physical agents

Index	Description
1	Occupational exposure to the agent is not qualitatively noticeable
2	The agent is detected, but the level is tolerable and appears to be below Action Level
3	The agent is detected as causing discomfort to employees, but exposure appears to be below OEL (Occupational Exposure Limit)
4	The agent is perceived and his exposure appears to be above OEL (Occupational Exposure Limit)

Table 3. Criteria for defining the exposure profile (frequency)

Multiplication result (Concentration-level Index) x (Exposure Time Index)		Exposure profile category
Tracks	1 to 3	2 – Remote
	4 to 7	3 – Unlikely
	8 to 11	5 – Occasional
	12 to 16	8 – Likely
	17 to 20	13 – Frequent

Table 4. Criteria for categorizing the effects on occupational health

Category	Health effects category
Light (2)	Reversible effects of little or no effect
Moderate (4)	Worrying Reversible Effects
Serious (8)	Severe Reversible Effects
Review (16)	Irreversible effects
Catastrophic (32)	Life threatening or disabling illness/injury

2.3.3 Risk assessment

The risk evidence shown in the exposure time classification along with concentration levels has been simplified as exposure profile indices, and the health effects have also been graded according to the potential for harm to the human organism, as proposed by NBR ISO 31010/2012 [12].

Based on this system, the assessment of occupational risk exposure was categorized by applying the "Occupational Exposure Grading Matrix or Risk Matrix" by multiplying the index assigned to the exposure profile by the category (degree) of health effects (Table 5).

The results of multiplying the exposure profile index by the degree of health effects were interpreted as a function of the level as very low, low, medium, high and very high (Table 5). Later, the acceptability of the risk was evaluated, as proposed by the Occupational Hygiene Standards [9-11].

- Very low and low risk: the condition is acceptable and no control measures are required;
- Medium and high risk: the condition is tolerable, preventive and corrective measures to reduce daily exposure will be necessary;
- Very high risk: The condition is intolerable and corrective measures must be taken immediately.

Table 5. Risk matrix for determining the level of risk in the workplace [11]

RISK MOTHER		FREQUENCY					
		WEIGHTS	2	3	5	8	13
SEVERITY	WEIGHTS		REMOTE	LITTLE LIKELY	OCCASIONAL	LIKELY	FREQUENT
	32	CATASTROPHIC	64	96	160	256	416
	16	CRITICAL	32	48	80	128	208
	8	SERIOUS	16	24	40	64	104
	4	MODERATE	8	12	20	32	52
	2	LIGHT	4	6	10	16	26

Subtitle

Risk Level
Very high (>160)
High (80 a 128)
Medium (26 a 64)
Low (10 a 24)
Very low (4 a 8)

In using the qualitative assessment of environmental risks it was possible to verify the need for qualitative assessments, as well as to analyze how the existing control conditions were being performed in the evaluated activities.

2.4 Data Analysis

Heat data (IBUTG) were obtained every five minutes to obtain an average value for each hour of the working day. These data were analyzed using descriptive statistics with mean and standard deviation. Noise and vibration data were analyzed qualitatively with systematic on-site observations.

2.5 Ethical Considerations

This study took into consideration the ethical principles, having the consent of the company and all workers for its accomplishment. It was submitted and approved by the Ethics Council of the Federal University of Espírito Santo (CAAE: 57864716.0.0000.5060), meeting the criteria established by Resolution No. 196/1996 of the Research Ethics Committee of the Ministry of Health, Brazil [13].

3. RESULTS AND DISCUSSION

3.1 Occupational Heat Exposure Assessment

Fig. 1 shows some parameters exceed that the tolerance limit, according to the NR 15 specifications, has been partially exceeded (13:00 to 14:00 hours in the logging and 14:00 to 15:00 hours in the wood processing industry). The NR 15 establishes that the tolerance limit for heat exposure in intermittent work is 26.7°C, coupled with rest periods at the workplace for activities classified as moderate [5]. Our results mean at these times the occurrence of unhealthy thermal overload was evident in the evaluated activities, advocating the need for adopting corrective and preventive measures.

Preventive measures are aimed at minimizing the likelihood of occupational heat exposure and should include periodic monitoring and medical exposure control, availability of water and mineral salts, training and information to workers, and permission to stop work when identifying conditions that are at risk to your health [6]. In contrast, corrective measures aim to reduce exposure to values below the considered tolerance limit, which involves process modification, use of reflective or absorbent barriers, ventilation adequacy, introduction of breaks, availability of acclimatized or thermally milder places can be highlighted [6].

It is important to note that within a few hours of heat assessment, the tolerance limit (26.7°C) is not exceeded, but IBUTG values are within a range which requires attention, as the values are in a high margin of proximity with those established by the standardization to characterize the activity as unhealthy [5]. It is also noteworthy that damage to workers' health resulting from exposure to heat does not only occur when the tolerance limit is exceeded [8]. This is a condition that will vary from individual to individual. Thus it is imperative that companies meet the requirements set forth in NR 7 and have implemented the Occupational Health and Medical Control Program (PCMSO) to monitor workers' health throughout their working lives [14].

3.2 Qualitative Analysis of Physical Noise and Vibration Hazards

3.2.1 Risk identification

The risk of noise and vibration has been identified in all operations covering logging, timber industry and wood processing activities. The sources of risks assessed in this study come from the machines used in the operations that make up these two activities (Table 6). The machines used mainly in the wood processing industry stand out for their poor conservation and lack of adequate protection measures. Brazilian law states that safety devices are part of preventive and corrective measures to minimize the likelihood of workers being exposed to risks in the workplace. When these measures are not considered in a work process, there may be damages to workers' health and, consequently, economic losses to the company [3].

3.2.2 Risk analysis

The results of the risk analysis applied to noise and vibration physical agents (Table 6) shows show that the risk was characterized as tolerable or intolerable. The condition most likely to be harmful to health was the exposure to noise in the wood processing industry, especially in operations related to the logging stages, where the risk was categorized as intolerable, determining that there should be immediate intervention to minimize damage caused by the agent [12].

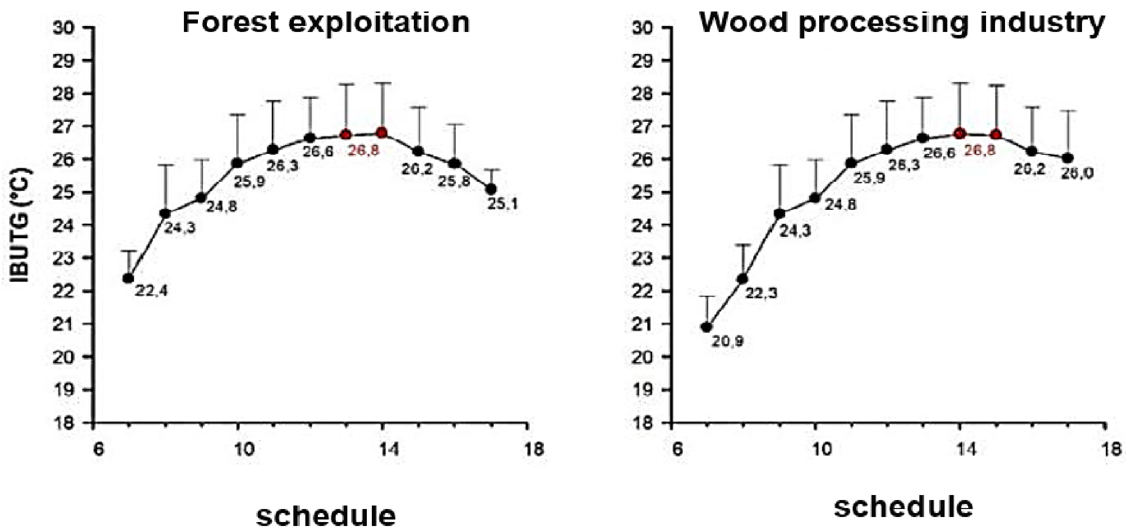

Fig. 1. Occupational heat exposure assessment. (a) Logging industry, (b) Wood processing industry

Table 6. Risk identification applied to the assessment of exposure of workers from logging extraction and wood processing industry to noise and vibration

Exposure operation	Major source of risk
Court	Chainsaw: used when felling and delimbing trees
Extraction	Forest tractor: used in the dragging of trees from the interior of the forest to the stockyard
Patio Operations: Logging	Chainsaw: used in the process of logging trees
Loading	Forestry tractor: used for log loading in transport vehicles
Transport	Vehicles: Used to transport logs to the wood processing industry
Log handling	Tractors: Used for unloading and stacking logs in the yard of the wood processing industry
Primary sawing	Simple vertical band saw: used in the process of reducing whole logs by longitudinal cuts into smaller pieces which may be planks, boards or pieces of rectangular or square section
Secondary sawing	Bench Circular Saw: Used in the process of defining the final dimensioning of wood pieces
Secondary cutting	Vertical Circular Saw: Used in setting the final length of the wood pieces as standard for sale
Manual packaging	Machines used in the primary unfolding, secondary unfolding and secondary unfolding operations, due to the proximity with which this operation is performed with the others
Loading of processed wood	Tractors: Used for loading lumber into transport vehicles

With respect to exposure to vibration (Table 7), the risk was higher in chainsaw operations in logging. In this case, it was possible to qualitatively analyze which occupational exposure limit (OEL) would be exceeded when the machine was in operation, representing risks to workers' health and safety. The risk was identified as medium in other operations, considering that the exposure was above the action limit according to the qualitative analysis, as recommended by NR 9 in its annex 01 [8].

3.2.3 Risk assessment

Through risk analysis, it was evaluated that factor which contributed to the risks not being categorized as intolerable in the logging activity was the exposure time. In performing the operations that constitute this activity, it was found that exposure to agents is intermittent, i.e. they do not occur continuously as observed in the wood processing industry. For example, the chainsaw operator remains effectively exposed

Table 7. Risk analysis applied to the assessment of exposure of workers from logging extraction and wood processing industry to noise and vibration

Exposure operation	Existing control measures	Exposure time *	Concentration or level	GHE profile	Health effects	Array result Exhibition categorization	Risk acceptability
Court	Use of EPI[N]	N** 4	4	8	16	High	Tolerable[N/V]
		V** 4	4	8	8	High	
Extraction	Not	N 4	4	8	16	High	Tolerable[N/V]
		V 4	3	8	4	Medium	
Patio Operations – Logging	Use of EPI[N]	N 4	4	8	16	High	Tolerable[N/V]
		V 4	4	8	8	High	
Loading	Not	N 4	4	8	16	High	Tolerable[NV]
		V 4	3	8	4	Medium	
Transport	Not	N 4	4	8	16	High	Tolerable[N/V]
		V 4	3	8	4	Medium	
Log handling	Not	N 4	4	8	16	High	Tolerable[N/V]
		V 4	3	8	4	Medium	
Primary sawing	Use of EPI[N]	N 5	4	13	16	Very high	Intolerable
		V 4	3	8	4	Medium	Tolerable
Secondary sawing	Use of EPI[N]	N 5	4	13	16	Very high	Intolerable
		V 4	3	8	4	Medium	Tolerable
Secondary cutting	Use of EPI[N]	N 5	4	13	16	Very high	Intolerable
		V 4	3	8	4	Medium	Tolerable
Manual packaging	Use of EPI[N]	N 5	4	13	16	Very high	Intolerable
		V 4	3	8	4	Medium	Tolerable
Loading of processed wood	Not	N 4	4	8	16	High	Tolerable[N/V]
		V 4	3	8	4	Medium	

** Exposure time: <12.5% of the workday (1); 12.5% to 25% of the workday (2); 25% to 50% of the workday (3); 50% to 87.5% of the workday (4) and> 87.5% of the workday (5); * Concentration or level: noticeable (1); below action level (2); below the tolerance limit (3), above the tolerance limit (4); * Profile of Homogeneous Exposure Group - GHE: remote (2); unlikely (3); occasional (5); likely (8) and frequent (13); * Health effect: mild (2); moderate (4); severe (5); critical (16) and catastrophic (32); **N= result statement assigned to environmental noise agent and V = result statement assigned to environmental vibration agent* to noise and vibration on average slightly more than 50% of the total working day time; for the rest of this time they travel to the location of trees for cutting and sharpen and lubricate the chainsaw devices. Moreover, the generation of the evaluated agents at qualitatively noticeable levels is not verified during this period. A similar situation of intermittent work cycles was also observed for the other forest exploration operations (extraction, loading and transportation).

In the wood processing industry operations, the combination of risk concentration and long exposure time characterized the acceptability of noise as intolerable for the most part. This result demonstrates the need for immediate interventions, as workers' health may be affected by exposure to this risk. In addition, among the existing control measures, only the use of PPE was verified to protect occupational exposure to noise. However, their use is not constant, and in some cases the PPE are in inappropriately used or are inappropriate themselves for the conditions, reducing their effectiveness, contrary to the Brazilian regulation (Regulatory Standard 06) that cites the company's obligation to provide employees, free of charge, appropriate PPE to the risk, in perfect condition and functioning [15].

It is noteworthy that the use of PPE is the last protection measure to be adopted in case the exposure to a certain risk present in the workplace is proven, according to the provisions of the Occupational Health and Safety Regulatory Standards [3]. Thus, it is necessary to prioritize collective protection measures which aim to eliminate, reduce or control the use, release and concentration of risk in the environment [8].

One of the main health hazards of workers related to continuous exposure to loud noise is occupational hearing loss, in addition to other effects including tinnitus, difficulty understanding speech in background noise and inability to locate sound sources [16-19]. Studies have shown that there is a higher probability of hearing loss in workers exposed to noise and vibration together. For example, a study of 199 Finnish forest workers found that aging was the main risk factor, followed by occupational noise exposure, and the presence of vibration in the work [20]. Furthermore, in the studies by Iki and Turcot greater hearing alterations were observed over time among forest workers who also suffered from white finger disease induced by hand and arm vibration [21,22]. In addition to causing communication difficulties, impairments related to hearing loss can in turn generate stress, anxiety, irritability, decreased self-esteem, social isolation, and loss of productivity, as well as impair the performance of activities of daily living, resulting in costs for the individual, family, company and society [23]. Thus, the potentialization of hearing loss in workers who are exposed to these two environmental agents is a matter of concern, especially in situations where no control measures are adopted, as observed in this study.

However, vibration not only contributes to hearing loss, it can also cause several other health problems to the worker, such as the onset of white finger syndrome caused by exposure of localized vibrations (hands and arms), resulting in a feeling of discomfort and moodiness, influencing performance and generating early degeneration of the lumbar region and herniated disc from exposure to whole body vibration [24, 25].

4. CONCLUSION

The assessment of occupational exposure to heat showed the need for implementing corrective measures, since exposure to this agent was characterized as unhealthy with the potential to cause damage to workers' health. The qualitative analysis of noise and vibration evidenced the need to adopt control measures because the risks in several operations were characterized as intolerable, and in the cases characterized as tolerable, the condition may worsen if the exposure time increases, indicating that the risks have the potential to cause harm in both evaluated activities.

ACKNOWLEDGEMENTS

This work was carried out with the support of the Higher Education Personnel Improvement Coordination - Brazil (CAPES) - Financing Code 001.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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DOI: 10.1007/bf00386476

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/51846