Assessment Of Vibration and Noise Levels Generated in The Steps Involved in The Mechanized Rice Processing Operations

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Abstract- Mechanization of rice processing to improve quality and quantity involves the use of machines that emit noise and vibrations, the intensity of which can be determined by measuring instruments to ensure a safe working environment. In this study, the noise and vibration generated in seven mechanized rice processing operations, including cleaning, steaming, drying, grinding, separating, destoning, and polishing, in a rice factory were evaluated for the risk analysis of workers' exposure severity in the work environment. The instruments used for data collection were a tape measure, a stopwatch (model XL-013), a sound level meter (SLM-25), and a vibration meter (WT 63A). The results showed that the steam processing operation has the highest idle (85.2 0.15 dBA) and production noise levels (88.5 0.92 dBA). During milling, the idle noise level is lowest (76.20 0.17 dBA), while during polishing the production noise level is lowest at 78.53 0.36 dBA. The steaming process produced the highest vibration level (6.13 × 0.10 (m/s)), while milling was the lowest (2.40 × 0.24 (m/s)). An analysis of variance test comparing the noise and vibration of the mechanized processing operations in a rice processing plant showed that the noise and vibration emitted were characteristics of the machine and the process involved and were significantly different ($p < 0.05$). The results showed that workers are at risk as the measured noise and vibration levels exceeded the allowable limit. Safety measures such as reducing workers' working hours and using personal protective equipment are encouraged.

Keywords Vibration, noise levels, mechanized, rice processing plants, rice processing operations.

1. Introduction

Rice processing plants have become one of the major small, medium and large-scale industrial activities through the mechanization of the labour process to meet the global market competition trend of industrialization. The mechanization of work processes to improve quality and quantity in different work environments creates noise and vibration. Studies have shown that exposure to vibration and noise in the work environment has become one of the greatest threats to workers' quality of life over the years due to the use of machines, sophisticated tools and other technological advances [1-5]. According to Haruna and Agu [6], noise generation from factory machinery is alarming because it not only affects the work environment but also penetrates the surrounding area. Although noise is associated with almost every work activity, some activities are associated with particularly high noise levels [3]. Heavy machinery used in factories vibrates and creates noise in the work environment. Anjorin et al. [3] emphasized that the high intensity of noise exposure at the workplace is not occupation- or country-specific, but a global phenomenon.

The operation of heavy machinery generates noise and is associated with severe whole-body vibration [7]. Noise and vibration are considered harmful physical agents in the environment and one of the main factors affecting workers' health and work efficiency [2]. Gosar et al. [8] explained that vibration from machinery at work can be either structural or acoustic and cannot be avoided but can be mitigated to specified levels to meet safe exposure limits and ensure workers' comfort. Vibrations in the work environment cause the surrounding air molecules to vibrate, resulting in a sine wave that reaches the human ear as sound. Although the human ear is not equally sensitive to all frequencies of sound-generating vibrations, vibrations sometimes complement loud sounds [9, 10]. Vibration is an environmental risk factor and is usually associated with noise in most work environments [1]. Though, Gosar et al. [8] claimed that, in most cases, vibration has little impact on human well-being. A counter report on the effects of vibration found ranges from fatigue, decreased work comfort, back pain, carpal tunnel syndrome, decreased dexterity and sensation and, decreased grip strength, and finger blanching [11-14].

The generation of noise or vibration depends on the operating mechanism of the equipment involved [3, 15]. The intensity of noise at the workplace is influenced by the number of machines in operation at the same time and the distance between the noise source and the workers [16-18]. The acceptable noise level in the workplace is 85 dBA averaging over eight hours. This standard does not mean that a safe condition exists below 85 dBA. It simply means that an 8-hour exposure of 85 dBA is considered an acceptable risk to hearing health in the workplace [3]. Exposure to noise at work above the recommended limit for a particular task makes workers irritable and reduces their productivity [19]. Exposure of workers to noise at work can lead to long-term health problems [20].

Workers in various mechanized work environments are exposed to vibration from machines in the workplace. This vibration can occur either locally or throughout the body, depending on the source (14, 21-27]. Whole-body vibration applied to a worker's body regardless of the working posture occurs through the bearing surfaces. Localized vibrations are primarily transmitted through contact with the worker's body, usually the hand. The human exposure limit to vibration for daily whole-body vibration exposure for action, established by the International Standards Organization (ISO) and accepted by the National Institute of Occupational Safety and Health [28] and the Occupational Safety and Health Administration, is 0.5 m/s, with a limit of 1.15 m/s for the frequency-weighted root-mean-square acceleration. To reduce hazards in any workplace, such as noise and vibration, and to reduce the negative impact of the operational process on human health and the environment, these prevailing hazards in the work environment should be measured and evaluated for control [29].

The introduction of mechanized operations in rice processing for necessities, human consumption and as an ingredient in medicine has meant that the manual milling method has steadily declined and machine mills have become more popular. Rice is an important commodity in every society and demand for it has increased in recent years. Rice has become the main staple food in around 33 countries worldwide, including Nigeria [30]. With a production value of 741.5 million tons, it is the third-highest agricultural product in the world [31]. About 85% of all rice production is for human consumption [32]. Given the status and growth pattern of rice processing and consumption worldwide, the rice milling industry has great potential to contribute significantly to job creation, boosting the economy and maintaining the country's food security [33, 34]. The import ban on foreign rice to Nigeria has had a positive impact on rice cultivation and rice production. The trend towards rice production and processing has recently reached a major peak, affecting more and more rice farmers, millers and other rice processing workers [35, 36]. As evidenced by the literature, rice milling has increased in some states, utilizing the production capacity of various rice mills across the country [33, 35, 37]. The establishment of rice mills in most parts of the country requires assessment and control of the processing, especially of the workers [36].

Rice processing involves critical steps to produce an edible part of a white or brown rice grain that is sufficiently milled and free of impurities for consumption [38]. Mechanizing rice processes to improve quality and quantity with machines that emit noise and vibration that can only be determined with the right measurement equipment. Several studies have been conducted to investigate the problem of occupational noise exposure in rice processing. A study by Prasanna Kumar et al. [39] found that noise from the rice milling machines poses a significant occupational hazard to rice mill workers, as workers' noise exposure levels are above the 8-hour exposure limit of 85 dB(A) for occupational health and safety. A study by Farouk and Zamman [40] found that rice mills generate significant noise levels in the workplace and surrounding area, which can cause health hazards both on-site and in the surrounding area. The effects of noise intensity in the mechanized rice mills conducted by Rinawati et al. [18] are hearing loss and impairment of work performance. Ogbuinya and Ohuruogu [36] study found that noise sources and activities of rice mills are rice cleaners, rubber roller hullers, compartment dividers, auxiliary sifting machines and an unenclosed electric motor. The study attributed the use of a long flat belt drive, a crank and steering column mechanism, the lack of an electric motor housing, poor machine maintenance and inadequate acoustic design of the rice mill work area as contributing factors to the observed noise generation in rice mills [36]. Despite the health issues encountered in rice processing operation, continued rice production cannot be ruled out [36]. The mechanized processes of rice production are not just limited to rice milling. Other mechanized rice processing operations include cleaning, steaming, drying, milling, separating, de-stoning and polishing. However, fewer studies have looked at the various machines in all rice processing plants that cause noise and vibrations in the rice processing plants. With this in mind, this study was conducted to quantify the noise emissions and vibrations generated at each point of the mechanized rice production process in a rice processing plant.

2. Materials and Method

2.1. Description of the Rice Processing Plant

This research was conducted at a rice processing plant with a production capacity of 100 tons per day of parboiled rice in Makurdi, Benue State, Nigeria. For this study, the levels of vibration generated and noise created in the steps of mechanical rice processing operations (cleaning, steaming, drying, milling, de-stoning, separating and polishing) to improve the quality and quantity of edible white rice grains sufficiently ground, free from contamination and for human consumption in the rice processing factory considered were assessed. Machines assessed include:

i. Paddy cleaner (60T/H cleaner; model TQLZ, Tonello Technologies) (Fig. 1a),

ii. Steam machine (13-15 T/h model SD- RMO12 manufactured by Zheng Zhou Sida Agriculture Equipment Co., Ltd) (Fig. 1b),

iii. Dryer (Model DLSG series manufactured by Zheng Zhou Sida Agriculture Equipment Co., Ltd) (Fig. 1c),

iv. Milling machine (5-7 T/h model MGLGQ36S manufactured by Kaifeng Maosheng Machinery Co. Ltd.) (Fig. 1d),

v. De-stoner (Dry Destoner 8-10T/h MTSD series manufactured by Kaifeng Maosheng Machinery Co. Ltd.) (Fig. 1e),

vi. Separator (5-7 T/h Model MGCZ manufactured by Kaifeng Maosheng Machinery Co. Ltd.) (Fig. 1f) and

vii. Polisher (4-6T/h model MPGW12.5 manufactured by Kaifeng Maosheng Machinery Co. Ltd.)All illustrations must be supplied at the correct resolution (Fig. 1g).

(a) Paddy cleaner

(b) Steam machine

(c) Dryer

(d) Milling machine

(e) De-stoner

(f) Separator

(g) Polisher

Fig 1. Rice processing machines

2.2. The Instrumentation Designs for This Study

The instrumentation designs for the vibration and noise level data collection are listed below:

i. A WT63A vibration meter (Shenzhen Wintact Electronics Co., Ltd.), shown in Fig. 2a, is an electronic device capable of processing vibration signals. It is a hand-held measuring device for the individual assessment of vibrations in machines and systems. The measuring range of the vibration meter is between 0.1 – 199.9 m/s² and its measurement frequency capability is around 10Hz to 15 KHz. The vibration meter is held in a hand device. It has a sensor that generates a voltage signal. This voltage signal is transmitted to the vibration meter via the cable. The vibration meter can process the voltage signal and display vibration values such as acceleration and speed. The vibration meter was used to measure the vibration exposure of the workers.

ii. The SLM-25 was used as the sound level meter, as shown in Fig. 2b. This model of sound level meter is compact and has a large LCD display. This model has a measurement range of 30 – 130 dB (A), an accuracy of 1.5 dB, a frequency range of 31.5 Hz to 8 kHz, frequency weighting of A and C and fast and slow time weighting, which the sound level meter also has an icon indicator for low power, and low range. The sound level meter is a handheld device with a microphone for acoustic measurements. This hand-held device was pointed at the machine to be assessed at a distance of at least 1 m.

iii. A 5-meter retractable tape measure (Generic Manufacturing Corporation, Temecula, California, USA), as shown in Fig. 2c, consists of a woven, plastic, fiberglass, or metal strip with linear measurement markings in millimeters (mm), centimeters (cm), meters (m) and feet (ft) and is commonly used in linear measurement. Accuracy is limited to 0.5 decimal places. This tape helps to take measurements from the location of the recorder to the point where the measurement is to be taken.

iv. The vibration values, duration and time interval were managed using a professional digital LCD handheld stopwatch, model XL-013 (Shijiazhuang Qjzl Network Technology Co. Ltd, China) (Fig. 2d). The digital professional hand stopwatch was recorded in seconds. It can measure a time interval of up to 0.1 seconds.

(a) Vibrometer (b) Sound level meter

(c) Measuring tape (d) Stopwatch

Fig. 2. The instrumentation designs for the vibration and noise level data

2.3. Work Schedule in The Rice Factory

The rice factory strategically improves workflow to optimize rice production, guided by a well-defined framework based on specific equipment, production capacity and local regulations. With a workforce capacity of 250 employees, the carefully developed work schedule provides for two shifts, morning and afternoon, each lasting 8 hours. Working a regular full-time shift results in a daily working time of 16 hours. Of the 250 employees, 105 are deployed per shift, with the exception of 10 employees who deal with packaging. Duties extend beyond workstations to include loading and unloading grain in each section. The distribution of workers per section and shift is as follows:

i. Cleaning (pre-processing): 20 employees take care of receiving, inspecting and cleaning the rice.
ii. Steaming: 10 employees supervise and monitor the steaming equipment.
iii. Drying: 15 employees ensure efficient dryer operation and grain monitoring.
iv. Grinding: 25 Staff manages the grinding machines and ensures proper shell separation.
v. De-stoning: 5 employees operate the stone removal equipment for thorough stone removal.
vi. Separation: 10 employees take care of sieves and separators for precise sorting of the rice.
vii. Polishing: 10 employees manage polishing machines and ensure product quality is maintained.

2.4. Data Collection Process

In this study, three basic measurements were considered; ambient noise, machine idle mode and production process noise and vibration of the machines involved in the rice cleaning, steaming, drying, milling, separating, de-stoning and polishing operations in which the machines were involved. Environmental noise was measured outside of working hours, while idle and production process noise was measured during working hours. The ambient noise differs from the prevailing background noise in the working environment. Idle noise is the noise the machines make after they are turned on with no rice processing activity taking place. Production noise was recorded during rice processing operation. A total of seven measuring points was carried out along the production line. In order to avoid noise effects or disturbances, the measurement was carried out while only one machine was in operation at a time. The noise was measured with the microphone approximately 1.5 m above the floor [41]. The direction of the SLM was aimed at the machine (the noise source) whose ambient, idle and production noise was assessed. The measurement devices were set up (the PC running the “Noise Logger Communication Tool” application), the SLM-25 sound level meter connected and a measurement profile set up to take a maximum of twenty (20) measurements with intervals of five seconds (5s) between each measurement. The recording was set to start manually by pressing the record button on the SLM-25 and stopped in the application software.

Several studies have documented that vibration can be transmitted across platforms that workers stand on and in these situations; The point of contact is the feet [23-25]. This information guided the measurement of vibrations at the floor of the rice processing plants where each of the machines were. The vibrometer's long probe was placed 1 meter long on the production floor alongside the sound level meter measurement set up. This distance was guided by the guidelines of Canadian Centre for Occupational Health and Safety for conducting the noise survey [42]. According to Gosar et al. [8], everything around us vibrates; therefore, the ambient vibration value of the processing floor of the rice plant was noted. This was followed by the machine idling and then the vibrations during the rice production process in the factory. Twenty measurements of ambient, idle and production vibration were taken and recorded using the WT 63A vibration meter with five seconds (5s) intervals between each measurement.

2.5. Statistical Analysis

The noise and vibration data obtained were evaluated according to ISO 9612:2009 (Acoustic guidelines for the assessment of noise exposure in a working environment) and ISO 2631-4, EVS-EN 5349-2 (Evaluation of mechanical vibration and shock of human exposure to vibration of the human body). The noise intensity categories on the typical noise level scale are listed in Tables 1 and 2 below.

Table 1. Noise level severity risk level criteria

S/N	Risk level	Noise level severity Criteria (dBA)
i	Tolerable risk	< 80
ii	Justified risk	> 80 – 85
iii	Unjustified risk	> 85 – 87
iv	Inadmissible risk	> 87 – 95
v	Intolerable risk	> 95

Reinhold and Tint [43]

Table 2. Vibration severity risk level criteria

S/N	Risk level	Noise level severity criteria (m/s²)	
		Whole-body vibration	Local vibration
i	Tolerable risk	<1.5	<1.0
ii	Justified risk	>1-5 – 2.5	>1.0 – 1.15
iii	Unjustified risk	>2.5 – 5.0	>1.15 – 8.2
iv	Inadmissible risk	>5.0 – 10.0	>8.2 – 16.0
v	Intolerable risk	>10.0	>16.0

Tint et al. [14]

The noise level and vibration data obtained from the survey for the rice processing operations cleaning, steaming, drying, milling, separating, de-stoning and polishing, and the associated environmental, idling and production characteristics were descriptively and statistically analyzed as minimum, maximum, mean, standard deviation (SD) and standard error of the mean (SEM). A one-way analysis of variance (ANOVA) was performed to compare the means of noise created and the means of vibration generated in the seven mechanized operations in the rice processing plant and determine whether there were significant differences within and between the groups considered

Significant at a 95% confidence level (p-value < 0.05). These analyzes were performed using the Statistical Package for the Social Sciences (SPSS) software, version 20.0. The result obtained was presented in tables.

3. Results and discussion

The statistical analysis of the noise and vibration data obtained with the devices, sound level meter (SLM-25) and vibration meter (WT 63A) from the seven mechanized operations operating during the rice production process in the rice processing factory, including cleaning, steaming, drying, grinding, separating, steaming, and polishing is shown in Table 3. From the results obtained and presented in Table 3, it can be seen that the average mean range of ambient noise levels outside of working hours was 38.13 – 40.0 dBA. The risk of the noise level criteria according to Reinhold and Tint [43] implies that all sections generate noise whose risk were tolerable (<80) (see Table 1). This means that the working environment did not contribute to occupational noise exposure in the rice production process. The idle noise results in different sections shown in Table 3 showed that steaming rice processing operation has the highest idle noise level; This produces an average mean of 85.20 ± 0.15 (SEM = 0.17) dBA while cleaning produces 84.40 ± 0.56 (SEM = 0.07) dBA. Next comes drying at 84.17 ± 0.23 (SEM = 0.03) dBA while steaming produces 79.60 ± 0.42 (SEM = 0.05) dBA. When cutting, no-load noise is 78.83 ± 0.85 (SEM = 0.11) dBA, when polishing it is 78.21 ± 0.08 (SEM = 0.01) dBA. Milling has the lowest idle noise with a value of 76.20 ± 0.17 (SEM = 0.02) dBA. When the noise level was subjected to the acoustic guidelines for the assessment of noise exposure in a working environment (ISO 9612:2009) (see Table 1), it was found that the mechanized rice processing operations in the factory, steaming, separating, polishing and milling were within tolerable risk severity criteria (<80 dBA), while cleaning and drying mechanical rice processing operations are within justified risk (>80 – 85 dBA). Only when steaming was an unjustified risk identified (>85 – 87 dBA). The results for production noise in different mechanized sections of the rice processing plant in the factory showed that steaming causes the highest production noise at 88.5 ± 0.92 (SEM = 0.12) dBA while cleaning causes 86.00 ± 0.73 (SEM = 0.12). Drying emits 85.0 ± 0.69 (SEM = 0.09) dBA while de-stoning emits 81.90 ± 0.49 (SEM = 0.06) dBA. When cutting, the production noise is 80.10 ± 0.24 (SEM = 0.03) dBA, while when milling, it generates 78.83 ± 0.22 (SEM = 0.03) dBA. Polishing has the lowest production noise with a value of 78.53 ± 0.36 (SEM = 0.05) dBA (Table 3). Interpretation of the noise level in the seven mechanized sections of the rice processing plant in the factory, the cleaning, steaming, drying, grinding, separating, de-stoning and polishing sections, using the acoustic guidelines of the international standards organization for the assessment of noise exposure in a working environment (ISO 9612:2009), adopted from Reinhold and Tint's [43] work, showed that the risk level criteria for the noise level of the steam, drying and cleaning sections present an unjustified risk (>85 – 87 dBA) leading to serious harm to workers such as fatigue, a decline in cognitive ability, difficulty concentrating, reflex muscle stress, psychological stress and tinnitus [43]. Grinding and polishing have a tolerable level of risk (<80 dBA) while steaming and separating rice processing operations have justifiable level of risk severity (>80 – 85 dBA), which can result in moderate psychological distress and mild difficulty in conversation. There was no section stating that the criteria for noise exposure, severity and risk level were inadmissible (>87 95 dBA) and intolerable (>95 dBA) risks.

Table 3. Statistical analysis of the noise levels in the seven mechanized section in rice processing factory for the rice production

Characteristics		Descriptive statistics				
Operations	Noise	Min	Max	Mean	SD	SEM
Cleaning	Ambient	38.10	41.90	40.00	1.34	0.17
	Idle	83.40	85.20	84.40	0.56	0.07
	Production	85.00	87.40	86.00	0.73	0.09
Steaming	Ambient	37.20	40.20	39.08	0.85	0.11
	Idle	85.00	85.40	85.20	0.15	0.02
	Production	87.20	90.50	88.50	0.92	0.12
Drying	Ambient	38.30	40.20	38.93	0.59	0.08
	Idle	83.90	84.50	84.17	0.23	0.03
	Production	84.10	86.40	85.00	0.69	0.09
Milling	Ambient	37.90	38.50	38.13	0.23	0.03
	Idle	75.90	76.40	76.20	0.17	0.02
	Production	78.40	79.10	78.83	0.22	0.03
Separating	Ambient	36.50	39.60	38.47	0.94	0.12
	Idle	77.40	80.10	78.83	0.85	0.11
	Production	79.70	80.50	80.10	0.24	0.03
De-stoning	Ambient	37.20	40.20	38.60	0.80	0.10
	Idle	79.00	80.30	79.60	0.42	0.05
	Production	80.90	82.70	81.90	0.49	0.06
Polishing	Ambient	37.70	40.10	38.67	0.73	0.09
	Idle	78.10	78.30	78.21	0.08	0.01
	Production	78.00	79.20	78.53	0.36	0.05

The results for ambient vibration, as shown in Table 4, is of the range of 0.12 - 0.19 m/s². This is within the tolerable vibration severity risk criteria. The machines idle vibration results showed that cleaning rice processing generated the highest idle machine vibration level with a value of 5.0 ± 0.12 (SEM = 0.02) m/s², followed by steaming rice processing with 5.0 ± 0.11 (SEM = 0 .01) m/s². De-stoning occurs at 4.27 ± 0.10 (SEM = 0.01) m/s² while separation occurs at 3.20 ± 0.14 (SEM = 0.02) m/s². Drying and polishing have 2.7 ± 0.00 (SEM = 0.00) m/s² and 2.60 ± 0.14 (SEM = 0.02) m/s², respectively. Milling which has 2.28 ± 0.13 (SEM = 0.02) m/s² generated the lowest idle machine vibration. Grouping of the various classifications of vibration exposure level for severity risk analysis shown in Table 2 of the mechanized rice operation vibration during rice cleaning, steaming, drying, milling, separating, de-stoning and polishing produce vibrations that may pose an unjustified risk (>2.5 – 5.0 m/s²) to workers, while milling produces vibrations that pose a justifiable risk (>1.5 – 2.5 m/s²) to workers. A comparison of the vibration exposure of the rice factory with the international standard organization for mechanical vibration and shock assessment of human exposure to whole-body vibration presented in Table 2 implies that with unjustified risk (>2.5 – 5.0 m/s²) exposure of workers up to 8 hours per day, such vibration can lead to occupational diseases such as reversible circulatory disorders which is unsafe. The results for production vibration showed that steaming has the highest vibration at 6.13 ± 0.31 (SEM = 0.04) m/s², followed by cleaning at 6.03 ± 0.10 (SEM = 0.01) m/s². When stoning, the production vibration was 4.70 ± 0.17 (SEM = 0.02) m/s², when separating, the vibration is 3.57 ± 0.26 (SEM = 0.03) m/s², when polishing, it was 2.97 ± 0.12 (SEM = 0.02) m/s². During drying, production vibration was 2.87 ± 0.27 (SEM = 0.04) m/s², while during milling, the vibration occurs at 2.40 ± 0.24 (SEM = 0.03) m/s² which was the lowest vibration level obtained (table 4). The vibration exposure levels determined in the cleaning and steaming areas of the rice factory according to the International Standard Organization for mechanical vibration and shock assessment of human exposure to whole-body vibration (see Table 2) are within the inadmissible severity level of the exposure risk as such can impose on the workers occupational disease such as irreversible circulatory disorders at 4-hour exposure per day [14]. The remaining five mechanized sections, steaming, separating, drying, grinding and polishing, emit vibrations with the severity of risk of exposure to workers within unjustified risk (>2.5 – 5.0 m/s²). The associated occupational disease with this vibration exposure level is a tendency to irreversible circulatory disorders when exposed to 8 hours per day. Machine vibrations are highly prone to occupational vibrations and therefore require appropriate inspection and maintenance of machines for faults.

Table 4. Statistical analysis of the vibrations in the seven mechanized section in rice processing factory for the rice production

Characteristics		Descriptive statistics				
Operations	Vibration	Min	Max	Mean	SD	SEM
Cleaning	Ambient	0.17	0.20	0.19	0.01	0.00
	Idle	4.90	5.20	5.00	0.12	0.02
	Production	5.90	6.20	6.03	0.10	0.01
Steaming	Ambient	0.16	0.19	0.18	0.01	0.00
	Idle	4.90	5.20	5.00	0.11	0.01
	Production	5.70	6.80	6.13	0.31	0.04
Drying	Ambient	0.17	0.20	0.18	0.01	0.00
	Idle	2.70	2.70	2.70	0.00	0.00
	Production	2.50	3.30	2.87	0.27	0.04
Milling	Ambient	0.16	0.18	0.17	0.01	0.00
	Idle	2.10	2.50	2.28	0.13	0.02
	Production	1.90	2.80	2.40	0.24	0.03
Separating	Ambient	0.16	0.18	0.17	0.01	0.00
	Idle	3.00	3.40	3.20	0.14	0.02

	Production	3.20	4.00	3.57	0.26	0.03
De-stoning	Ambient	0.10	0.14	0.12	0.02	0.00
	Idle	4.10	4.40	4.27	0.10	0.01
	Production	4.40	4.90	4.70	0.17	0.02
Polishing	Ambient	0.15	0.18	0.16	0.01	0.00
	Idle	2.40	2.80	2.60	0.14	0.02
	Production	2.80	3.10	2.97	0.12	0.02

The analysis of variance test was used to compare the variances in the average mean of noise and vibration exposures in the seven mechanized sections of the rice processing plants. The results of the analysis of variance highlight the statistical significance of each effect that results from comparing the mean squared with an estimate of experimental error. The summary of the analysis of variance for the noise level in the rice processing plant is presented in Table 5. The *F*-value is the ratio of the variance group means to the within-group mean variances, used to determine the magnitude of variability. The *p*-value serves as a tool to check the significance of each coefficient, which in turn is necessary to understand the pattern of interactions between the test variables. A significance level of 5% was used, meaning that all terms with a *p*-value less than 0.05 were considered significant. The significance of the coefficient from the noise and vibration of the mechanized rice process revealed a large value for the *F*-value and smaller magnitude for the *p*-values. Analysis of the variance test revealed a high *F*-value for idle (4063.02) and production (2673.43) noise, meaning that within-groups, the variability was relatively large. The *p*-values obtained at a 95% confidence level were less than 0.05, indicating that there was a significant difference in the idle and production noise of the machines in the seven mechanized rice processing sections of the rice processing plant (Table 5). The summary of the analysis of variance (ANOVA) for vibration is also shown in Table 5. The *F*-value statistical test used to determine whether the variability of the group means for vibration in the rice processing plant sections was large for idle and production vibrations relative to the within-group variability. Analysis of variance showed that idle and production vibration in the seven sections used to determine vibration were all significant (p-value < 0.05). The variation in noise created and vibration generated by the various machines in the seven sections of rice processing plants in this study was consistent with work in the literature that the generation of noise or vibration depends on the operating mechanism of the equipment involved [3,15].

Table 5. Analysis of variance for noise levels in the rice processing plant work environment

Descriptions			Sum of Squares	Mean Square	Df	*F*-value	*p*-value
Noise	Idle	Between Groups	4603.15	767.19	6	4063.02	0.00
		Within Groups	77.98	0.19	413		
	Production	Between Groups	5370.67	895.11	6	2673.43	0.00
		Within Groups	138.28	0.34	413		
Vibration	Idle	Between Groups	850.48	141.75	6	2822.65	0.00
		Within Groups	20.74	0.05	413		
	Production	Between Groups	0.19	0.03	6	268.85	0.00
		Within Groups	0.05	0.00	413		

Given to the significant difference in the results of the ANOVA for the noise level and vibration exposure during machine idle and production operation, a post hoc Tukey analysis was then carried out. The aimed at identifying specific difference between the rice processing steps – cleaning, steaming, drying, milling, separating, de-stoning and polishing. The reference groups arranged in Table 6 are listed in column 1, while the comparison groups are shown in row 1 with differences in means. The post hoc Tukey test revealed Significant differences in the mean values differences between the rice cleaning process and all other rice processing steps - steaming, milling, separating, stoning and polishing, except drying ($p < 0.05$) (Table 6). This result implies that the statistical significant difference of the noise levels during the rice processing operations. Furthermore, negative mean differences in noise levels during rice milling compared (reference group) to separating, stoning and polishing suggest that the latter processes had higher mean values of noise emissions, contributing to a comprehensive understanding of noise dynamics during rice processing operations.

Also during rice production processing, the post hoc Tukey test was used to determine which specific step in the rice processing group (cleaning, steaming, drying, milling, separating, stoning and polishing) or which groups are different from each other. The paired wised comparison results between the groups showed that there is a significant difference between the groups but not statistically significant ($p > 0.05$) between the rice milling and polishing processes. The noise generated during rice milling and polishing was not significantly different as the corresponding paired wised comparison was higher than 0.05 ($p < 0.05$) (Table 7). Consequently, there was a negative mean difference in the paired wised comparison between the reference group (cleaning) and the comparison group (steaming). The rice milling process (reference group) also had negative values compared to separating, de-stoning and polishing (comparison group). This means that the mean of the reference groups was lower than that of the comparison group.

Table 6. Post Hoc Tukey HSD Tests Multiple Comparisons for Idling machine noise levels in the rice processing plant work environment

RG/CG	Cleaning	Steaming	Drying	Milling	Separating	Destoning	Polishing
Cleaning		-0.8000*	0.2333	8.2033*	5.5717*	4.8000*	6.1867*
Steaming			1.0333*	9.0033*	6.3717*	5.6000*	6.9867*
Drying				7.9700*	5.3383*	4.5667*	5.9533*
Milling					-2.6317*	-3.4033*	-2.0167*
Separating						-0.771700*	0.6150*
De-stoning							1.3867*

Note *. The mean difference is significant at the .05 level; RG: Reference group; CG: Comparing group

Table 7. Post Hoc Tukey HSD Tests Multiple Comparisons for production noise levels in the rice processing plant work environment

RG/CG	Cleaning	Steaming	Drying	Milling	Separating	Destoning	Polishing
Cleaning		-2.4950*	1.0033*	7.1717*	5.9000*	4.1000*	7.4683*
Steaming			3.4983*	9.6667*	8.3950*	6.5950*	9.9633*
Drying				6.1683*	4.8967*	3.0967*	6.4650*
Milling					-1.2717*	-3.0717*	0.2967
Separating						-1.8000*	1.5683*
De-stoning							3.3683*

Note *. The mean difference is significant at the .05 level; RG: Reference group; CG: Comparing group

The post hoc test tests multiple comparisons of the seven steps in the rice processing operations during the idle mode of the machines; cleaning, steaming, drying, milling, separating, de-stoning and polishing shows that mean differences are significant at the $p < 0.05$ level for all paired wised comparisons of the rice processing operations, except for the paired wised comparison results between the rice cleaning and steam processing operations (Table 8). In addition, the rice steaming process has a higher vibration exposure mean value compared to the vibration exposure mean value during the rice cleaning process, resulting in a negative mean difference in the result of the paired wised comparison. The post hoc Tukey tests showed that the vibration exposure of workers during the rice separating, de-stoning and polishing processing group is on average higher than during rice milling when the machines are in idle mode.

The p-values obtained in the paired wised comparison of the seven steps of rice processing during the machine operation excluding the paired wised comparison of the rice processing operations of milling and separating and steaming and drying showed statistical significance differences between the groups. Table 9 showed that all vibration exposures of all reference groups of the seven steps of rice processing had statistically higher mean values compared to the comparison groups, so that no negative mean differences occurred in the paired wised comparison of the seven steps.

Table 8. Post Hoc Tukey HSD Tests Multiple Comparisons for Idling machine vibration exposure in the rice processing plant work environment

RG/CG	Cleaning	Steaming	Drying	Milling	Separating	Destoning	Polishing
Cleaning		-0.0983	3.1600*	3.6300*	2.4633*	1.3267*	3.0633*
Steaming			3.2583*	3.7283*	2.5617*	1.4250*	3.1617*
Drying				.4700*	-0.6967*	-1.8333*	-0.0967
Milling					-1.1667*	-2.3033*	-0.5667*
Separating						-1.1367*	0.6000*
De-stoning							1.7367*

Note *. The mean difference is significant at the .05 level; RG: Reference group; CG: Comparing group

Table 9. Post Hoc Tukey HSD Tests Multiple Comparisons for production vibration exposure in the rice processing plant work environment

RG/CG	Cleaning	Steaming	Drying	Milling	Separating	Destoning	Polishing
Cleaning		0.0100*	0.0100*	0.0200*	0.0233*	0.0700*	0.0300*
Steaming			0.0000	0.0100*	0.0133*	0.0600*	0.0200*
Drying				0.0100*	0.0133*	0.0600*	0.0200*
Milling					0.0033	0.0500*	0.0100*
Separating						0.0467*	0.0067*
De-stoning							-0.0400*

Note *. The mean difference is significant at the .05 level; RG: Reference group; CG: Comparing group

4. Conclusion

This research assessed the noise created and vibration generated by the mechanized processing operations in a rice processing factory at selected production sites (cleaning, steaming, drying, milling, de-stoning, separating, and polishing) and also identified the potential for noise exposure and vibrations caused on the workers in the rice plant. It showed that the occupational risk of exposure to machine vibration and noise levels in the rice processing plant was well above the standard occupational safety exposure limit during rice production processes. Prolonged exposure to such noise and vibration can cause health complications and discomfort to the operator. Based on this study, some control measures should be taken, including the following:

- Proper maintenance and servicing of the machine should be ensured.
- Workers should be provided with personal protective equipment to protect them against occupational exposure to noise and vibration in the work environment.
- Reduce workers' working hours' and time spent operating machinery.

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