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Noise-induced Hearing Loss in Workshops and Laboratories in Kenyan Universities

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Abstract Noise-induced hearing loss in workplaces is a challenge, which may lead to accidents and interference with communication. In order to protect workers and students exposed in engineering workshops and laboratories, it is important to determine the magnitude and understand causative factors to adequately address the problem. The present study aimed at identifying predisposing factors that lead to noise-induced hearing loss in public universities in Kenya. The study was conducted in 10 technical universities, identified through purposive non-probability quarter sampling from a population of 49. Noise profiling was used to identify and characterize sources and types. An integrating sound level meter was used to record the noise levels for the different clusters and results compared with statutory requirements. Existing controls for noise pollution were also assessed. The results show that a large proportion (84.1%) of the noise types identified was continuous. The continuous noise emanated mainly from hand grinding (18%) and internal combustions engines (25%) with resultant values being above the statutory upper action limit of 85 dBA. The sources of impulsive noise were mainly intermittent actions of electric-powered (47.6%) and manually-operated (52.4%) tools. Impulsive noise levels were found to be below the maximum permissible exposure limit of 140 dBA. Although one of the universities had a safety and health committee and a risk management department, hearing protection was not used by those exposed. Noise-induced hearing loss in workshops and laboratories in public universities in Kenya is likely to occur from continuous noise exposure since there are inadequate control measures taken.

Keywords: *noise-induced hearing loss, causative factors, Kenya, universities*

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1. Introduction

The extent and magnitude of the burden of occupational accidents and diseases to society can be correctly predicted when reliable evaluation of underlying causes is done. In developed economies, the International Labour Organization (ILO) evaluation criteria are applied to generate statistics that are regularly updated and reported. Planning for preventive actions based on reliable information ensures reduction in adverse impacts and improvement in quality of work environment. This is not the case in middle and low-income economies; a number of challenges make it difficult to collect appropriate information. These challenges range from lack of sufficient resources to poor or undeveloped safety culture. Estimates generated by ILO for countries without data are not representative of the actual situations, and therefore there is need for a more proactive approach to this problem.

Though a number of ILO Conventions and Resolutions have been adopted and domesticated by most countries worldwide, information of occupational accidents is not standardized. Developing countries do not have reliable information management systems on their occupational accidents and diseases due to lack of proper recording and notification protocols. One of the most common occupational hazards that cuts across workplaces is noise. Review of literature on noise-induced hearing loss (NIHL) by Lie et. al. [1] indicates that up to 21% of hearing loss is caused by occupational exposure to excessive noise. This is also confirmed by studies conducted by Wang et. al. [2], who found that noise exposure over time causes a shift in the threshold of hearing as with increase in age. In addition, Desharies, et al. [3] established that noise was a risk factor that affected communication, and contributed to workplace accidents and fatalities.

Humans perceive noise [4,5] within a particular range [20 to 20,000hertz (Hz)], with variations resulting from hereditary predisposition and genetics. Within the audible range, particular levels at the different frequencies define the limits within which hearing can be safely perceived. Normal hearing threshold defines the minimum levels in order to perceive sound, while the threshold of discomfort defines the level above 110 decibels A-scale (dBA) where hearing becomes uncomfortable. Above130 dBA, hearing becomes painful and this defines the threshold of pain. Exposures to 140 dBA noise levels may lead to permanent hearing loss. This is supported by legislation that prohibits exposures to such noise levels [6]. While the human ear may recover from noise exposure levels of 80 dBA and below, it has been found that noise levels above 85 dBA may result in hearing loss and therefore hearing conservation programs must be implemented. This has been the basis of noise legislation to protect against adverse noise effects.

Generally, for continuous noise, 80 dBA is considered the lower exposure action level while 85 dBA is the upper action level. At the lower action level, the human ear is capable of recovery of noise-induced hearing effects [7] while at the upper action limit, damage to hearing may occur [8]. When the noise level ranges between 80 and 85 dBA, hearing protection is not compulsory but should be made available to workers for their comfort and protection. Above the upper action level, hearing protection equipment is compulsory, and therefore must be used at all times. Action limits are meant to prevent noise hazards and act as threshold triggers of potential noise exposure problems. In learning environments where communication and sound perception are key, the maximum noise levels should not exceed 40 dBA [9]. In addition, the Occupational Safety and Health Act [10] (OSHA) prohibits worker exposure to noise levels in excess of 90 dBA in any 24-hour duration.

Two common types of industrial noises are impulsive and continuous noise. Impulsive noise occurs when there is a sudden acoustic pressure wave transmission over very short times and at large amplitudes, and has been found to cause sudden and severe hearing loss [11], which is greater than that resulting from continuous type of noise [12]. Permissible noise exposure from impulsive noise has been capped at 140 dBA. Exposure should not exceed this value at any given time.

At the apex of an effective noise-control strategy is engineering interventions. Other layers of control options may be added to supplement the efforts of mitigation of noise pollution. These may include management controls [13], which involve the development of procedures to be followed by those predisposed, and the use of personal and collective protection systems [14]. Effectiveness of the use of these additional layers of control depends to a large extent on the accuracy with which the extent of the problem is established; either through direct measurement or through theoretical evaluation. This is a proactive approach to the problem of excessive noise exposure.

Kenya has a total of 49 Chartered Universities [15]. Out of these, 31 are public while 18 are private. One of the objectives of university education is to provide skills and competencies to meet human resource requirements and conduct research for development. It is therefore imperative that environments representative of the labour market are used for the development of desired competencies. A number of occupational challenges have been documented in university education. According to Odhiambo [16], universities in Kenya face academic quality assurance challenges. In addition, Mukhwana, et al. [17]. observes that when reporting on the status of university education in Kenya, challenges with academic programs and staffing, income and expenditure are highlighted, but acknowledgement of potential impacts of lack of effective implementation of occupational safety and health systems that may affect quality was left out. This situation is worsened by weak legislation and enforcement [18], which may encourage complacency.

Researches on noise pollution in universities in Kenya are not well documented, but several studies have been carried out in other countries where noise levels were found to be below 80 dBA [19,20,21] under similar conditions. However, available literature on the levels of noise exposure in industrial settings in Kenya indicate an underlying cause of occupational hearing loss among workers [22,23,24]. Academic activities rely heavily on modes of communication that ensure knowledge and concepts are passed on from tutors to learners. Sometimes it becomes important to use practical demonstrations to enhance understanding [25]. The efficacy of the learning process is therefore dependent on the clarity of the communication channels used. These channels may be affected by levels of background noise around the learning environment [26]. The objective of this study was to establish predisposing factors that have the potential for NIHL in public universities offering engineering education in Kenya.

2. Materials and Methods

2.1. Sampling Technique and Equipment

Purposive non-probability sampling technique was used in this study to select the sample from a population of 49 chartered public universities in Kenya [15]. A sample size of 10 universities, representing 20.4% of the population, offering engineering-related programs [27] with practical sessions in workshops and laboratories were selected. The universities were arranged in ascending order based on the number of workshops and laboratories in each, and coded (U-1 to U-10). The number of workshops and laboratories in each university with potential to generate noise were identified and documented through noise profiling. These workshops and laboratories were then classified into various categories: machining, foundry, construction plant equipment, agricultural machinery, automotive engines, carpentry equipment, thermodynamics, welding processes, activities involving impulsive noise, and special unrelated. Equipment and tools (e.g., milling equipment, grinders etc.) in the workshops with potential for excessive noise generation were identified and the list used to guide data collection. Activities that did not fall into any of the noise source and common among the sample population were categorized as “special unrelated” and evaluated separately.

Noise levels were recorded using a 1:1 octave band integrating sound level meter. Pre-and post-measurement calibration of the meter was done to 94dB. Calibration data were automatically stored in the instrument, and later downloaded together with the sampling data.

2.2. Data Collection and Analysis

Background noise levels were recorded for each of the sampling sites in order to identify and isolate other sources other than sources under test. Appropriate correction of the background noise was done according to ISO Standard [28]. During data collection of both continuous and impulsive noise types, the sound level meter was held on a tripod stand at a location approximately 1.2m above the ground and 1m from the noise source, care being taken to minimize reflection from adjacent features. The meter was pre-set to record noise levels over a 2 to 15-minute duration depending on the task. This was done for each activity at steady-state condition; the duration conveniently being selected to ensure that interruptions from other sound sources were as minimal as possible since measurements were taken during normal working hours. Three (3) sets of data were collected from each of the identified workshops/laboratories in each university, with average values of continuous and impulsive noise types being recorded separately. The noise measurements were then normalized over an 8-hour working day equivalent values ($L_{Aeq, 8}$).

A total of 111 and 21 data were recorded for continuous and impulsive noise levels respectively. Mean values for both categories of noise levels were determined for every sampling site (i.e., U-1 to U-10). For each sub site (e.g., machining workshop), continuous noise levels from all related activities were logarithmically combined to determine the resultant noise level. The resultant noise levels were used to establish the maximum possible impact on hearing. The resultant noise levels were then presented in graphical form and compared with maximum permissible exposure limit (PEL) of 90 dBA and upper action limit (UAL) of 85 dBA to prevent noise hazard set by the OSHA [10]. For impulsive noise, recorded values were evaluated against the maximum permissible limit (140 dBA) that defines acute exposure of an unprotected ear.

A further categorization of the noise sources was made in order to make direct comparisons throughout the sample population. These subgroups are as indicated in Table 1.

Table 1. Sources, types, and subgroups of noise generating activities

S.NO.	Sources of noise	Type of noise	Activities generating noise
1	Machining workshop	Continuous	Milling, surface grinding, drilling, lathe work, gear hobbing
2	Foundry workshop	Continuous	Oil burner, air blower
3	Construction plant equipment workshop	Continuous	Heavy plant equipment engines
4	Agricultural machinery workshop	Continuous	Noise from tractors (35, 75, 90, 100, & 130 hp)
5	Automotive engines workshop	Continuous	Stationery IC engines, air compressors
6	Carpentry equipment workshop	Continuous	Surface planning, thicknessing, ripping, & cross-cutting, air compressor, jig sawing
7	Thermodynamics laboratory	Continuous	IC engines
8	Welding processes workshop	Continuous	Hand grinding, gas cutting
9	Activities involving impulsive noise	Impulsive	Sheet metal forming; impact on wood; impact on metal
10	Special unrelated	Continuous	*Unrelated activities

In Table 1, *unrelated activities included those not common throughout the 10 sampling sites, and therefore direct comparison may be difficult.

Safety control measures put in place by management of the various universities to minimize the impacts of noise on hearing were also assessed. This was achieved through collection of descriptive data via desktop review and observations. Outcomes from analysis of the management safety control measures put in place were compared with statutory environmental and occupational safety and health requirements [6].

3. Results and Discussions

3.1. Characteristics of Workshops and Laboratories in Universities Studied

From a total of 49 chartered public universities considered, 10 of them met the sampling criteria. The 10 universities were characterised in terms of the number of available workshops and laboratories, and the number of activities (e.g., grinding or milling etc.) that generate either continuous or impulsive noise (Table 2). Out of the 10 universities, U-10 had a total of ten workshops and one laboratory with potential for excessive noise generation. This implies that there were more activities in U-10 compared to all others which had fewer. Both U-1 and U-2 had only one workshop each with seven potential noise generation activities, while 50% of the universities sampled had less than five (5) workshops and laboratories with potential noise sources. Two distinct types of noise were identified, i.e., continuous and impulsive.

Table 2. Characteristics of workshops and laboratories in the universities studied

University	Workshops and laboratories		Sources of continuous noise		Sources of impulsive noise	
	No.	%	No.	%	No.	%
U-1	1	2.0	7	6.3	1	4.8
U-2	1	2.0	7	6.3	2	9.5
U-3	3	6.0	9	8.1	1	4.8
U-4	3	6.0	12	10.8	2	9.5
U-5	4	8.0	6	5.4	2	9.5
U-6	5	10.0	9	8.1	2	9.5
U-7	6	12.0	10	9.0	2	9.5
U-8	8	16.0	15	13.5	3	14.3
U-9	8	16.0	13	11.7	3	14.3
U-10	11	22.0	23	20.7	3	14.3
Total	50	100	111	100	21	100

When both continuous and impulsive noise sources were considered, continuous noise sources were predominant at 84.1%, and these were mainly rotating machines. On the other hand, impulsive noise emanated from material forming processes in which repetitive impulsive forces were applied.

3.2. Noise Levels

The recorded background noise levels for all the sampling sites ranged from 32 to 45 dBA. This was attributed to noise from birds and occasional charting of students making their way to and from lectures. Since the differences between the background noise and that produced by the various noise sources were more than 15 dBA, a correction factor of zero applied [28].

3.2.1. Continuous Noise from Machining Activities

Out of all the noise data recorded, 111 (84.1%) constituted continuous noise and the rest impulsive noise. Activities that resulted in continuous noise included: machining, foundry, construction plant equipment, agricultural machinery, automotive engines, carpentry equipment, thermodynamic lab and welding processes.

a) Machining workshops

A large proportion (72.7%) of machining activities including milling, drilling and tool grinding generated noise levels exceeding the upper action limit of 85 dBA (Figure 1). Out of these, 36.4% exceeded the 90 dBA threshold exposure level prohibited by OSHA [10]. This is attributed to the fact that in the affected sites (U-1, U-2, and U-5), several activities were carried out at the same time within these locations, thereby raising the resultant noise exposure levels and predisposing users to NIHL. At site U-3b where new and modern computer-numerical controlled machines were located, the resultant noise level of 65.4 dBA was within the lower action limit and therefore exposure level was acceptable. Therefore, the use of hearing protection at this site is optional. None of the machine workshops had any controls such as periodic medical examination, communication through safety signages, installation of excessive noise detectors, and the use of individual and collective hearing protective devices.

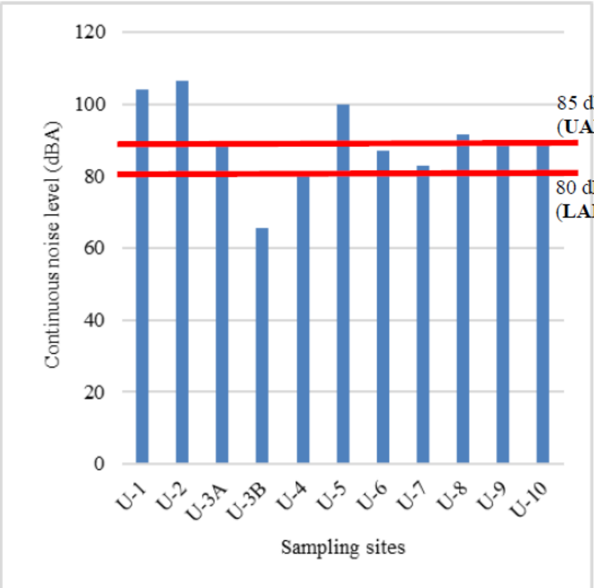

Figure 1. Continuous noise levels for machine workshops at different sampling sites. UAL, upper action limit; LAL, lower action limit [29]

b) Foundry workshops

Activities in foundry workshops (Figure 2) that generated continuous noise included the use of oil-fired furnaces, blowers and extraction fans. Out of the three sites with foundry workshops, U-7 and U-8 had resultant noise levels of 62 and 65 dBA respectively, while U-10 had 86 dBA which exceeded the upper permissible limit, thereby predisposing students and staff to NIHL. Though safety signages regarding hot surfaces and splashing metals were present in all the three sites, signages relating to excessive noise exposure were absent. No audiometric examination of students and staffs had been carried out in the last one year.

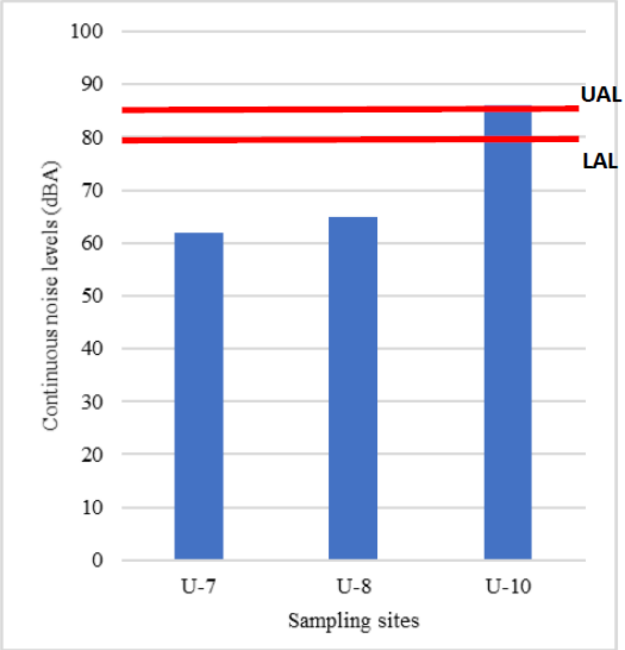

Figure 2. Continuous noise levels from activities within the foundry workshops at different sampling sites

c) Heavy construction plant equipment

The noise generated from heavy construction plant equipment was predominantly from compression ignition internal combustion diesel engines. Other sources included air compressors and associated tools. Readings were taken at idling condition and resultant level when all equipment were turned on. The noise levels were recorded for two sites, U-8 and U-10 and they corresponded to 93.2 and 97 dBA, respectively (Figure 3). These levels were well above the upper action limit of 85 dBA and the maximum permissible level of 90 dBA. This indicated that workers at these workshops were more likely to develop NIHL over time, since the use of control measures including personal hearing devices were not provided.

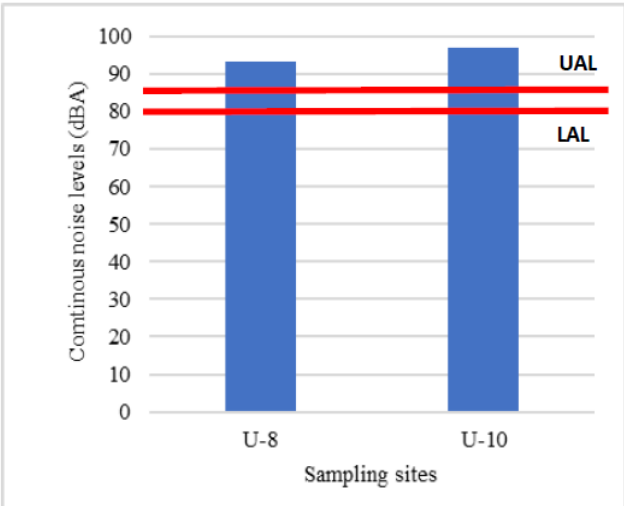

Figure 3. Continuous noise levels for heavy construction plant equipment at different sampling sites

d) Agricultural machinery workshops

The noise generated in the agricultural machinery workshops (Figure 4) were mainly due to compression ignition internal combustion tractor engines of 35, 75, 90, 100, and 130 horsepower. Other sources included air compressors and the use of associated air tools. The levels were taken at idling condition, and it was projected that the levels of 93.5 dBA at U-5 and 100.6 dBA at U-10, which were well above the upper action limit and the maximum permissible exposure limit of 90 dBA, were likely higher at maximum operating conditions. This was likely to significantly impact on users hearing and lead to NIHL since no hearing protection and controls were present to supplement the tractor mufflers. This category of equipment is also likely to impact a wider population of workers since it is not possible to protect all those exposed in a practical situation in the farm.

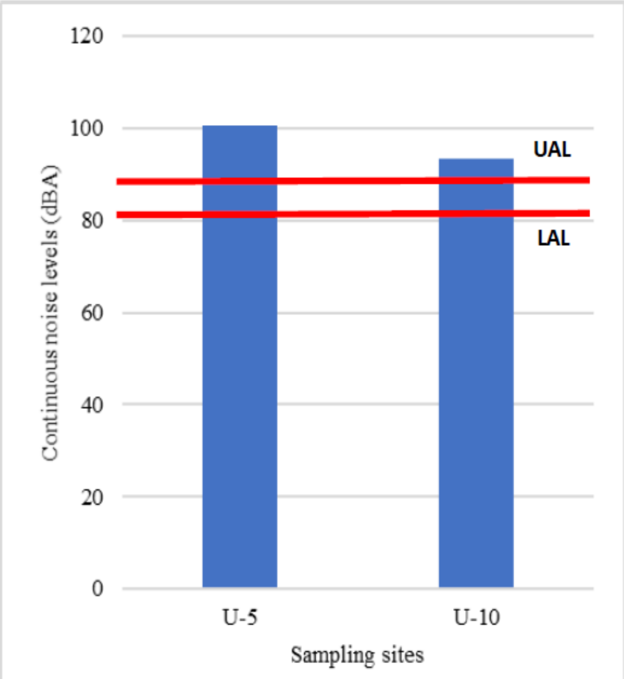

Figure 4. Continuous noise levels from agricultural machinery workshop sources at different sampling sites

e) Automotive workshop

Continuous noise generated from automotive workshops (Figure 5) included that from stationery diesel and gasoline internal combustion engines, and model cars that varied in age from very old (more than 30 years) to new (less than five years). Other sources of continuous noise included air compressors and associated air tools. It was observed that noise in the two sampled sites, U-7 (97.2 dBA) and U-10 (98 dBA) were well above the upper action limit of 85 dBA and the maximum permissible exposure limit of 90 dBA, thereby predisposing users to adverse effects of excessive noise including NIHL. It was also observed that there was neither use of personal protective equipment for both staffs and students exposed nor control measures such as relevant noise signages and excessive level detection and alarm devices, thereby increasing their chances of being affected by high noise levels.

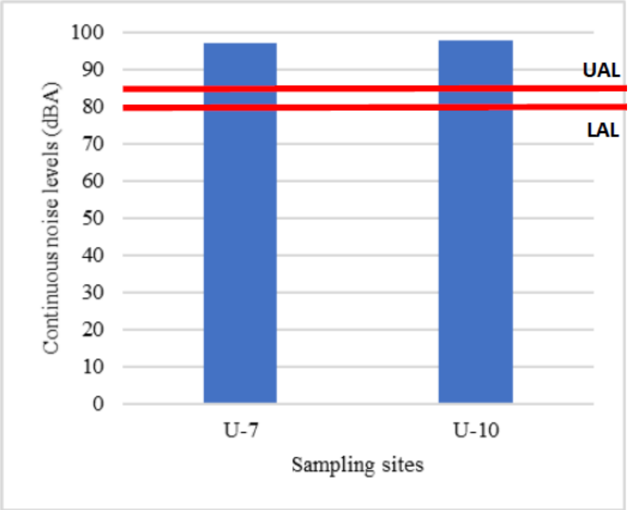

Figure 5. Continuous noise levels from automotive workshops sources at different sampling sites

f) Carpentry workshops

Activities in carpentry workshops that generate continuous noise were those related to timber processing activities including surface planning, rip sawing, cross cutting, jig sawing, and thicknessing. Wood processing equipment operate at very high speeds with most of the tools having multi-cutters that generate noise through structural vibration and periodic impact on the pieces to be cut as part of the cutting process. The results show that all the four sampled sites had noise levels above the upper action limit of 85 dBA and the maximum permissible noise level of 90 dBA (Figure 6). It was observed that no personal or collective hearing protective equipment were in use at all the four sites, predisposing those exposed to NIHL and other adverse effects of excessive noise exposures. Further, appropriate noise safety signages were not in place in any of the said locations.

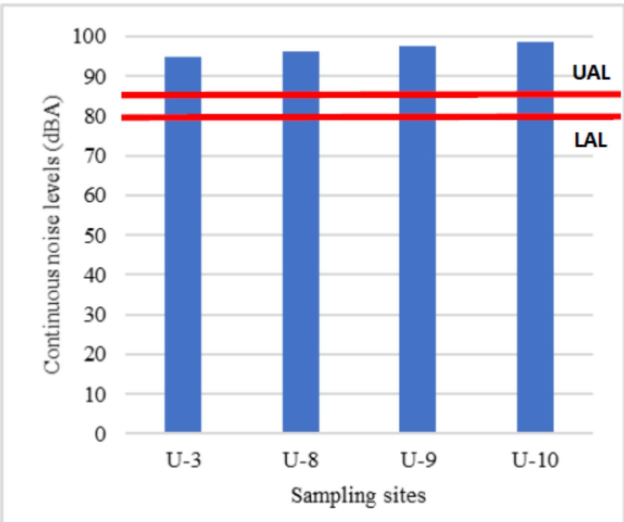

Figure 6. Continuous noise from carpentry workshop sources at different sampling sites

g) Thermodynamics laboratory

Continuous noise generated in thermodynamics laboratories arise from an assortment of internal combustion engines and jet engine models. Typical exposure varied depending on the experiments being carried out, and these ranged from idling state to the maximum load conditions provided through dynamometers. The results show that all the sites sampled had noise levels well in excess of the upper action limit and the maximum permissible exposure limit thereby predisposing staffs and students to NIHL and other related adverse effects (Figure 7). In all the sites, there were no personal or collective hearing protection measures including periodic medical examination and audiometric tests.

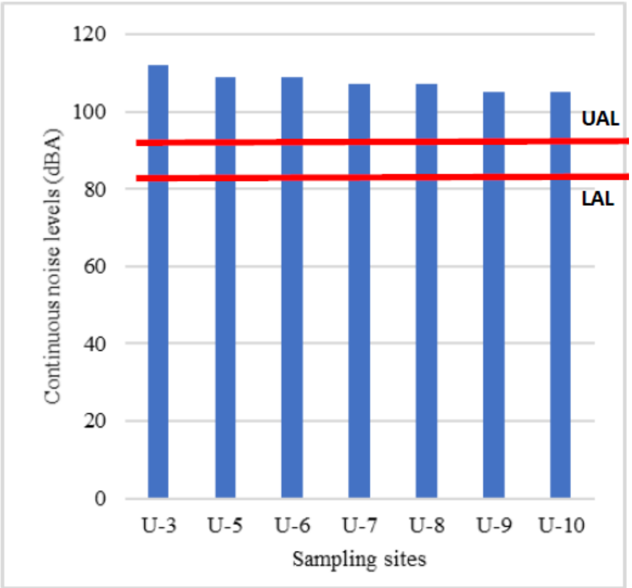

Figure 7. Continuous noise levels from thermodynamics lab sources at different sampling sites

h) Welding workshop

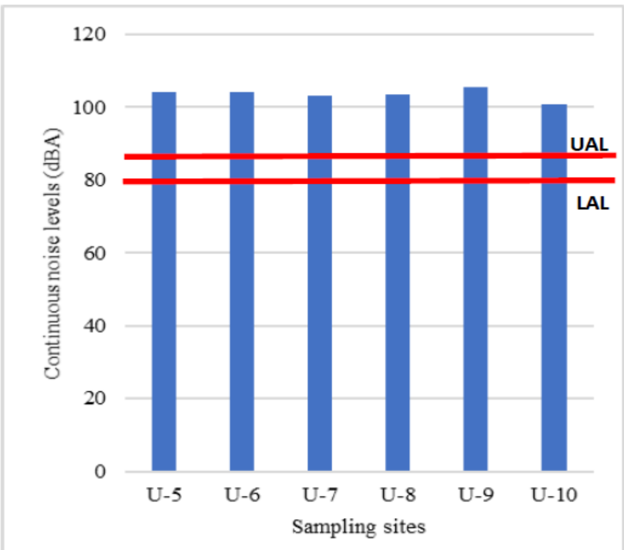

Figure 8. Continuous noise levels from welding workshop sources at different sampling sites

In the welding workshops continuous noise was generated from activities such as metal cutting, hand grinding and oxy-acetylene gas cutting. Noise levels also depended on materials being cut, material thickness, and the methods of restraining the work while being processed. A loosely held sheet metal will produce higher noise levels compared with a firmly held one with less overhang. All the sampled sites had noise levels exceeding the recommended thresholds (Figure 8). None of the sampled site complied with occupational exposure limits in terms of noise generated and measures in place to protect those exposed. There was thus high likelihood of suffering from impacts of exposure to high noise levels from welding workshops in the universities sampled as was the case with thermodynamics lab and carpentry workshops.

i) Unclassified noise sources

A category for activities that were not common in all the sampling sites were categorised as unclassified noise sources. These included mineral processing lab (U-4) activities as dry grinding, sieving and grading; combined foundry, welding and electrical installation lab (U-4) generating continuous noise from furnace burner, hand grinding and gas cutting; testing of model jet engine in the aerospace engineering lab (U-7); and activities within the innovation workshop (U-10) including hand grinding, abrasive cutting and noise from air compressor.

In this category, all sampled sites generated noise levels above the upper action limit and maximum permissible noise exposure levels, thereby predisposing both staffs and students to adverse effects of excessive noise exposure (Figure 9). In addition, there were no control measures in form of appropriate posters and use of personal and collective hearing protective devices to minimize exposure levels.

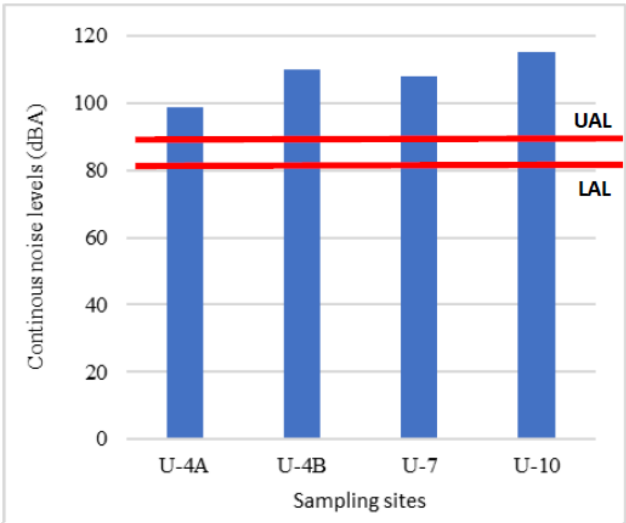

Figure 9. Continuous noise levels for other workshop activities at different sampling sites. U-4A, mineral processing lab; U-4B, foundry workshop; U-7, aerospace engineering lab

Overall, continuous noise was the most common type of noise in all the universities and accounted for a higher proportion (>90%) of chances of NIHL in laboratories and workshops offering engineering-related programmes in Kenya. These results confirm similar findings Long-term effects of occupational noise exposures above the upper action limit of 85 dBA and permissible maximum exposure limit of 90dBA for continuous noise type in laboratories and workshops in public universities in Kenya are a risk factor potentially capable of leading to noise induced hearing loss (NIHL). Continuous noise from internal combustion engines (100 dBA maximum) and impulsive noise from manual material forming processes

(114 dBA peak) were identified as potentially injurious to occupational health and safety. Strategies in place internally, and externally including legal compliance requirements and supervision by relevant government agencies were not sufficient to prevent NIHL. There is, therefore, need to develop, implement and maintain management programs and engineering controls both at institutional and government levels that will not only address the noise risks but all other inherent occupational risks. that workshops and laboratories in universities generate noise above safe levels that may be injurious to safety and health of staffs and students.

3.2.2. Impulsive Noise Sources

Impulsive noise was generated from activities involving shaping of metal – sheet metal forming, impact on metal and impact on wood during joining. When combined with continuous noise, a total of 25 (17.9%) impulsive noise data were collected. While sheet metal forming was common in all the ten sampled sites (Figure 10), impact on metal was recorded in 80% of the sites and impact on wood in 30%. Though all the noise levels recorded were below the peak limit of 140 dBA, there was need to develop good work practices to minimize impulsive noise generated, and in addition, explore the use of quieter processes for prolonged activities involving the use of methods generating impulsive noise. Such alternatives could be the use of benders for sheet metal and quieter power tools for nailing onto wood.

The population at high risk of hearing loss as a result of noise exposure were students and workshop staff. The longest time spent by students during practicals in all the sample sites was 3 hours per day and once a week for each subject requiring practical exposure. This gives time for students exposed to recover from effects of exposure to continuous noise as established by Kang [30]. On the other hand, workshop staff were engaged in activities that spanned over the 8-hour work day, 5 days a week for the entire duration of employment. This predisposed staff to higher risks of developing occupational noise-induced hearing loss as in previous studies [31] On average, impulsive noise was generated in at least two major activities (use of electrically powered and manually operated tools) in each of the universities. Exposure to this type of noise may affect both the student and staff in the same manner if the magnitude of the offending sound is above safe levels. Cumulative effects of impulsive noise are likely to be different for students and staff members due to the overall duration of exposure. Genetic predisposition of each exposed person (staff and students alike) may influence the type of impact to health and safety caused by noise [32].

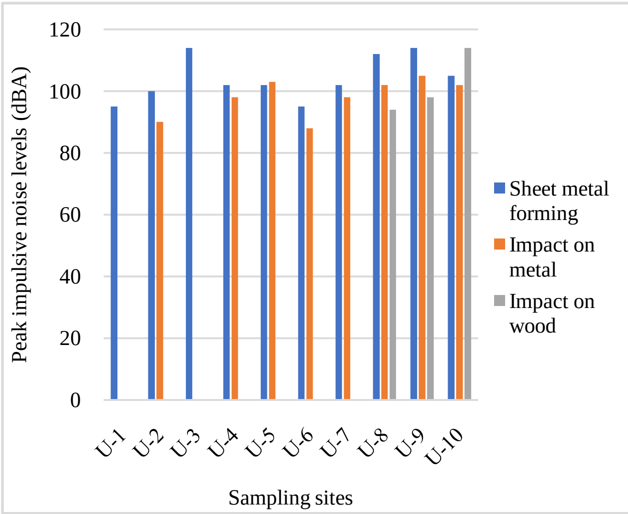

Figure 10. Peak impulsive noise levels for various workshops at different sampling sites

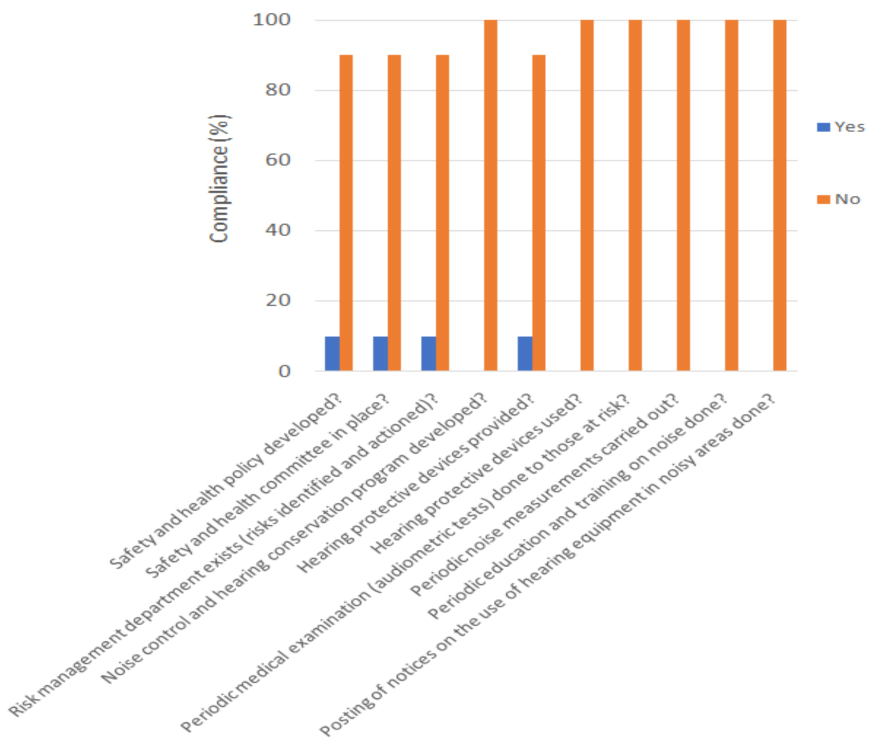

Figure 11. Comparison of levels of compliance with management controls

3.3. Impact of Management Controls in NIHL Prevention

The role of management in the prevention of NIHL is important, and for this reason, its impact was evaluated. Aspects of management considered are summarized in Figure 11. Majority (≥ 90%) of the universities did not have any management controls in place to minimize the occurrence of NIHL. Only one university (U-10) had an occupational safety and health policy, a safety and health committee and a risk management department to evaluate the risks and action them, and occasionally provided hearing protective equipment. However, these provisions were not enough to lower the chances of NIHL among staffs and students since the values of continuous noise levels record for this university were above the upper action limit of 85 dBA, with some instances exceeding the maximum permissible exposure level of 90 dBA.

4. Conclusion

Long-term effects of occupational noise exposures above the upper action limit of 85 dBA and permissible maximum exposure limit of 90dBA for continuous noise type in laboratories and workshops in public universities in Kenya are a risk factor potentially capable of leading to noise induced hearing loss (NIHL). Continuous noise from internal combustion engines (100 dBA maximum) and impulsive noise from manual material forming processes (114 dBA peak) were identified as potentially injurious to occupational health and safety. Strategies in place internally, and externally including legal compliance requirements and supervision by relevant government agencies were not sufficient to prevent NIHL. There is, therefore, need to develop, implement and maintain management programs and engineering controls both at institutional and government levels that will not only address the noise risks but all other inherent occupational risks.

Acknowledgements

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