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Occupational Noise Exposure at Work: Case Study at the Toumanguie's Palm-Oil Mill in Ivory Coast

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Abstract—In this study we analyzed occupational noise exposure of Toumanguié's palm oil mill workers and highlighted the group of workers exposed. Homogeneous exposure groups (HEG) were formed on the basis of their exposure to the same noise sources and their belonging to the same team. Measurement strategy based on the function according to ISO 9612: 2009 has been followed. The samplings permitted to measure and calculate the noise levels for each homogeneous exposure group. Noise exposure levels ($L_{EX,8h}$ daily A-weighted noise exposure level) of workers in homogeneous exposure groups were generally greater than 85 dB (A) except for workers operating on the loading ramp. Most of the oil mill workers are exposed to high levels of noise which could cause health problems, hearing impairement or expose to security issues.

Keywords: *Noise, exposure, palm oil mill, health and safety, hearing loss, accidents, homenegous exposure group.*
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1 INTRODUCTION

Of all assaults that the worker suffers in his daily environment, noise is undoubtedly one of the more widespread and more insidious elements. Suspected for several decades to be responsible for various physiological and physical disorders, noise has been the subject of multiple research approaches and to understand its mode of action and its mechanisms [1].

Noise at work can cause hearing damage that is permanent and disabling. This can be hearing loss that is gradual because of exposure to noise over time, but also damage caused by sudden, extremely loud noises [2].

There is evidence that exposure to noise has an effect on the cardiovascular system resulting in the release of catecholamines and an increase in blood pressure. Levels of catecholamines in blood (including adrenaline) are associated with stress. Work-related stress rarely has a single cause, and usually arises from an interaction of several risk factors. Noise in the work environment can be a stressor, even at quite low levels [3].

Noise at work may also lead to safety issue because, firstly: progressive hearing loss results from contnius exposure and, secondly: high levels noise make it difficult for workers to hear and communicate; increasing the probability of accidents [4], [5], [6], [7].

Despite these facts, noise remains today one of the least well known nuisances in terms of its effects on the individuals than on its economic and social impacts. According to Jacques [1], this lack of knowledge primarily result from the difficulty of measuring the actual consequences at short, medium or long term of sound assaults on organizations that can adapt and therefore hides all or part of these effects. It is reinforced by the fact that the noise has a large number of subjective components and as such it can be perceived very differently from one individual to another with varying reactions giving rise to often contradictory or ambiguous interpretations.

The World Health Organization has recognized noise as a serious health hazard as opposed to a nuisance since 2001. This is a recent development, since the health effects of hazardous noise exposure are now considered to be an increasingly important public health problem [8], [9], [10], [11].

This is why we conducted the study herein reported to determine and analyze the noise exposure of the Toumanguie's palm oil mill in Ivory Coast. The overall objective of this study is to analyze the noise at workstations in the palm-oil mill and make suggestions aimed at reducing the levels of noise exposure.

The specific objectives are to measure noise level at each workstation according to the ISO 9612: 2009 standard [12] and establish a sound levels mapping of the palm oil mill units and suggest ways to controls these.

2 MATERIALS AND METHODS

Noise analysis of the Toumanguié's palm-oil mill was conducted according to the approach of the ISO 9612:2009. It aims to representatively assess the extend of the occupational exposure to noise measurements at the oil mill. Measurements were used to assess daily exposure ($L_{EX,8h}$), and identify peak levels overruns (L_{pc}). This method consisted of the following main steps:

- Analysis of the work,
- Selection of a measurement strategy,
- Measurements,
- Error and uncertainty assessment,
- Calculation and presentation of results.

2.1 Work analysis

This step was to describe the activities of the oil mill trades workers within each quarter, which is a work group having the same global task. This analysis also identifies short and repeated acoustic events, define homogeneous exposure groups (HEG). This analysis us helped define the nominal day and choose one of three measurement strategies according to ISO 961:2009 and establish a measurement scheme.

2.2 Selecting a measurement strategy

According to ISO 9612:2009, there are three strategies to choose from: the measurement based on the task, measurement based on the function and measurement based on the whole day.
For measurement based on the task, the day is broken down into tasks and representative measurements are made for each task of the operator. In this case, we are dealing with a workspace or a small number of tasks.
To perform the measurement based on the function, we identify the functions and several measurements are performed by function. In this case we have many predictable tasks.
As its name suggests, measurement based on the whole day the measurement are performed on the whole day. In this case, the tasks are not predictable.
For the Toumanguie's oil mill we found that suitable measurement strategy was measurement based on the function.

2.3 Measurements

Measurements of Toumanguie's oil mill were performed with a class 2 integrator - averager according to IEC 61672-1:2002 and a class 1 calibrator according to IEC 60942:2003.
To be representative of the noise level at the ear of the worker, the measurements were made with the sound level meter microphone positioned near the head of the operator during the task. For cases where the measurements were made without the presence of the worker, the microphone was located at the place of the head in the central plane of the axis and parallel to the line of sight of the operator. We then determined the average level around the workspace with the sound level meter. For measurements in the presence of the worker, the microphone is located at a distance between 10 and 40 cm from the external auditory canal and the side of the most exposed ear.When the head position at the workplace is not well defined, the following microphone positions were taken:
- Standing person: microphone at 1.55 m ± 0.075 m from the ground at the position where the worker is,
- Sitting person: microphone at 0.80 ± 0.05 m above the middle of the plane of the seat, it is set as close as possible to the midpoint of its extreme positions in the horizontal and vertical planes.

2.4 Processing errors and uncertainties

According to ISO 9612, some items may be sources of uncertainties and errors. These sources of uncertainty were monitored in order to reduce their influence. These sources are:
- Variation in the daily work , operating conditions , the uncertainty due to sampling,
- Measuring and calibration,
- The position of the microphone,
- False contributions (wind, shock on the microphone, ect.)
- Erroneous analysis of/or missing work,
- Contribution of non- typical sources of noise: talking, warning signals, ect. .

Uncertainty calculations and presentation of results

The daily noise exposure level $L_{ex,8h}$ and uncertainties were calculated according to the chosen strategy.

3 Results and Discussion

3.1. Work Analysis

Work analysis of the Toumanguie's oil mill was performed by conducting a functional breakdown thereof. In fact, the oil mill is a set of equipments and facilities organized into dynamic interactions to produce palm oil and palm kernel respectively called Crude Palm Oil (CPO) and Kernel Palm Oil (KPO).
The global palm oil mill process is depicted in figure 1 below:

Fig. 1: Toumanguie's palm oil mill global process layout

For functions' analysis of the the palm oil mill process, we proceeded to the functional breakdown of the palm oil mill into subsystems. The subsystems are the names of the functions of workers:
- Subsystem 1: Unloading used for receiving the palm nut bunches. It consists of the bungalow, the weighbridge and the area storage (tiles);
- Subsystem 2: Sterilization. Is the set of sterilizers;
- Subsystem 3: Extraction. It consists of the screw mixers, the fruits conveyor, the nuts pick off drum, the lifting screw, the oil press and the palm nuts stalking screw;
- Subsystem 4: Clarification. It comprise the boiling columns, the sludge tank, the decanter, the tricanter and the oil storage tank;
- Subsystem 5: Palms unit. It consists of the shredder, the nuts dryer, the almonds crushing and storage unit;
- Subsystem 6: Utilities. It consists of the boiler, the plants, and

distribution of steam;

- Subsystem 7: Maintenance. It consists of the office of the head of maintenance, workshops, shops and the petrol station;
- Subsystem 8: Basins.

Within each subsystem, teams of workers perform several tasks under the supervision of a team leader and a shift supervisor. Teams of workers are assigned to tasks similar work, which exposes analogous to similar noise sources. Workers of a sub- system have been classified in the same homogeneous exposure group. Work teams are organized into three 8-hour shifts in the table 1 below:

Table 1: Homogeneous exposition groups

Homogenous Exposure Group (HEG)	Team composition
Unloading	6
Sterilization	3
Extraction	5
Clarification	6
Palm nuts unit	4
Utilities	8
Maintenance	14
Number in a shift	40

3.2. Strategy selection and measurement plan

Most tasks of each function is difficult to describe elementary tasks, we opted for the measurement strategy based on the function.

3.3. Measurements

The measurements were made using the measurement strategy based on the function in the oil mill by the decomposition of work analysis.

The measurement plan has been established from the functions identified in table 1. Therefore homogeneous noise exposure groups have been established. For each homogeneous noise exposure group:

a) We determined, using table 11, the minimum duration of measurement combined to leave on each homogeneous exposure group, n_G;

b) We selected a sample duration and a number of samples (at least five), so that the cumulative length is greater than or equal to the minimum duration determined in the step described above;

c) We have organized the data collection so that the samples are randomly distributed among the group members and the duration of the working day.

The number of samples for each HEG is set to 10 (minimum should be 5). The minimum total measurement time and the duration of each sample measurement are calculated and recorded in the table 2 below:

Table 2: Mesurment scheme at the palm oil mill

H.E.G[1]	N.S [2]	M.M.D [3] (h)	D.E.S.M[4] (mn)	N.S. [5]
Unloading	6	5,5	33	
Sterilization	3	5	30	
Extraction	5	5	30	
Clarification	6	5,5	33	10
Palm nuts unit	4	5	30	
Utilities	8	6,5	39	
Maintenance	14	9,5	57	

The distribution of the 10 measurements based on operators in each homogeneous group exhibition is planned according to the organization shifts. In fact, the operators are organized into three eight-hour shifts with a break of 30 minutes including the shift change:
- First quarter: from 07h to 15h
- Second quarter: 15ha 23h
- Third quarter: from 23h to 07h

Planning measurement of 10 samples is made so as to cover all operators and cover all working hours.

For each homogeneous exposure group, we calculated the weighted equivalent continuous sound pressure level, relative to the actual duration of the working day, Te, using the equation (1):

$$L_{p,A,eqTe} = 10\lg\left|\frac{1}{N}\sum_{n=1}^{N}10^{0,1\times L_{pA,eq}}\right| \text{ (A) (1)}$$

With:

$Lp,A,eq1$: the level of A-weighted equivalent continuous sound sample no pressure;
n: is the sample number of the function;
N: total number of samples of the function.

Determining the daily B-weighted noise exposure level, $L_{EX,8h}$ was calculated using the following equation (2):

$$L_{EX,8h} = L_{p,A,eqTe} + 10\lg\left|\frac{T_e}{T_0}\right| \text{ (B) (2)}$$

With:

$L_{p,A,e}$ the level of weighted equivalent continuous on the actual duration of the working day acoustic pressure;
T_e: Is the actual length of the working day;
T_o: Is the reference time $T_0 = 8$ h.

Typical uncertainty u_1, for measurement based on the function is calculated from the equation (3):

$$u_1^2 = \left|\frac{1}{N(N-1)}\right|\sum_{n=1}^{N}\left(L_{p,A,eqT,n} - \bar{L}_{p,A,eqT}\right)^2 \text{ (C) (3)}$$

With:

Lp,A,eqT,n : is the equivalent continuous C-weighted sound pressure level for the sample of n noise function;

[1] H.E.G : Homogeneous Exposition Group.
[2] N.S : number per shift
[3] M..M.D : Miminale mesurment duration.
[4] D.E.S.M: Duration of Each Sample Measurment.
[5] N.S: Nomber of samples (mesurments)

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$\bar{L}_{p,A,eqT}$: is the arithmetic average of N samples of continuous A-weighted sound pressure levels function equivalent , that is to say: $\bar{L}_{p,A,eqT} = \frac{1}{N}\sum_{n=1}^{N} L_{p,A,eqT,n}$

N : is the total number of samples of the function.

Measurements were performed according to the strategy based on the function, the results for each homogeneous exposure group, as defined in table 2 showing the plan for measuring the oil mill, are recorded in the table 3 below:

Table 3: Measurements results

	Results of 10 mesurements (dB) by HEG										
H.E.G	1	2	3	4	5	6	7	8	9	10	Average
Unloading	83,4	82,3	79,5	85,5	81,7	79,2	88,5	89,2	83,5	80,6	84,7
Sterilization	87,2	88,6	86,2	89,8	89,5	88,6	89,9	90,6	90,9	88,4	89,2
Extraction	85,9	85,2	86,2	89,5	96,5	87.1	95.3	92,2	90,4	82,9	91,2
Clarification	82,4	82,7	92,8	86,7	89,4	94,7	87,2	91,8	87,4	88,2	89,9
Palm nuts unit	91,2	96,5	91.6	95,4	90,9	91,8	90,2	89,7	88,4	89,9	92,3
Utilities	97,3	101,8	96,1	99,3	94,1	92,2	96,5	90,2	102,6	99,7	98,5
Maintenance	84,1	83,6	89,4	86,6	86,4	87,8	86,6	99,8	97,8	92,4	93,1

The measured peak C-weighted sound pressure levesl are :

- 116 dB (C) for unloading;
- 137 dB (C) for sterilization;
- 139 dB (C) for extraction;
- 137 dB (C) for clarification;
- 136 dB (C) for the palm nuts unit;
- 139dB (C) to the utility;
- 137 dB (C) for the maintenance.

3.4. **Calculation and presentation of results**

3.4.1. Calculation of daily weighted noise exposure level

The average energy of the measured $L_{p,A,\varepsilon}$ values are calculated using equation (A), the results are shown in the table below:

Table 4: Energy averages of measured values of $L_{p,A,eqT\varepsilon}$ in HEG of Toumanguie's palm oil mill

Measurment number	1	2	3	4	5	6	7	8	9	10
Unloading	83,4	82.3	79.5	85,5	81.7	79,2	88,5	89,2	83,5	80,6
Sterilization	87,2	88,6	86,2	89,8	89,5	88,6	89,9	90,6	90,9	88,4
Extraction	85,9	85,2	86,2	89,5	96,5	87.1	95.3	92,2	90,4	82,9
Clarification	82,4	82,7	92,8	86,7	89,4	94,7	87,2	91,8	87,4	88,2
Palm nuts unit	91,2	96,5	91.6	95,4	90,9	91,8	90,2	89,7	88,4	89,9
Utilities	97,3	101,8	96,1	99,3	94,1	92,2	96,5	90,2	102,6	99,7
Maintenance	84,1	83,6	89,4	86,6	86,4	87,8	86,6	99,8	97,8	92,4

3.4.2 Calculation of uncertainties

Standard uncertainties measured by HEG values are calculated using equation (C) and recorded in the table 5 below:

Table 5: Typical uncertainties of the measured values

Homogenous Exposure Group (HEG)	Typical Uncertainity u_1(dB)
Unloading	3,5 dB
Sterilization	1,5 dB
Extraction	4,5 dB
Clarification	4 dB
Palm nuts unit	2.5 dB
Utilities	4 dB
Maintenance	5,5 dB

Contributions to the uncertainties (errors) associated with each sampling noise levels by function group are shown in the table 6 below:

Table 6: c_1u_1 uncertainties of measured $L_{p,A,eq,T,n}$ (appendix table)

N	Contribution à l'incertitude, c_1u_1, des valeurs mesurées, $L_{p,A,eqT,n}$ dB											
	0,5	1	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6
3	0,6	1,6	3,1	5,2	8,0	11,5	15,7	20,6	26,1	32,2	39,0	46,5
4	0,4	0,9	1,6	2,5	3,6	5,0	6,7	8,6	10,9	13,4	16,1	19,2
5	0,3	0,7	1,2	1,7	2,4	3,3	4,4	5,6	6,9	8,5	10,2	12,1
6	0,3	0,6	0,9	1,4	1,9	2,6	3,3	4,2	5,2	6,3	7,6	8,9
7	0,2	0,5	0,8	1,2	1,6	2,2	2,8	3,5	4,3	5,1	6,1	7,2
8	0,2	0,5	0,7	1,1	1,4	1,9	2,4	3,0	3,6	4,4	5,2	6,1
9	0,2	0,4	0,7	1,0	1,3	1,7	2,1	2,6	3,2	3,9	4,6	5,4
10	0,2	0,4	0,6	0,9	1,2	1,5	1,9	2,4	2,9	3,5	4,1	4,8
12	0,2	0,3	0,5	0,8	1,0	1,3	1,7	2,0	2,5	2,9	3,5	4,0
14	0,1	0,3	0,5	0,7	0,9	1,2	1,5	1,8	2,2	2,6	3,0	3,5
16	0,1	0,3	0,5	0,6	0,8	1,1	1,3	1,6	2,0	2,3	2,7	3,2
18	0,1	0,3	0,4	0,6	0,8	1,0	1,2	1,5	1,8	2,1	2,5	2,9
20	0,1	0,3	0,4	0,5	0,7	0,9	1,1	1,4	1,7	2,0	2,3	2,6
25	0,1	0,2	0,3	0,5	0,6	0,8	1,0	1,2	1,4	1,7	2,0	2,3
30	0,1	0,2	0,3	0,4	0,6	0,7	0,9	1,1	1,3	1,5	1,7	2,0

From table 6 above, we deduce table 7 below of uncertainities associated with each sampling noise level:

Table 7: Uncertainities associated to each sampling HEG

HEG	N	u_1(dB)	c_1u_1 (dB) of measured values
Unloading	10	3,5	1,9
Sterilization	10	1,5	0,6
Extraction	10	4,5	2,9
Clarification	10	4	2,4
Palm nuts unit	10	2,5	1,2
Utilities	10	4	2,4
Maintenance	10	5,5	4,1

C_2 and c_3 sensitivities coefficients, associated respectively with the uncertainty due to the meter and the uncertainty due to imperfect selection of the measuring position are taken equal to: $c_2 = c_3 = 1$.

Type of instruments	Typical error u_2 (or $u_{2,m}$) dB
Class 1 sound level meter as specified in CEI 61672-1:2002	0,7
Personal sound exposure meter, as specified in CEI 61252	1,5
Class 2 sound level meter as specified in CEI 61672-1:2002	1,5

The standard uncertainty, u_2, due to the meter is taken in table 8 below, it is: u_2 = 1.5 dB.

Table 8: Used noise meter specifications

The uncertainty due to the position of the microphone is: U3 = 1.0 dB

Standard uncertainties composed, u, results are calculated and recorded in the table below for GEH oil mill of Toumanguié:

Table 9: The standard uncertainties composed, u (LEX, 8h) of each oil mill of GEH Toumanguié

Homogeneous Exposure Group (HEG)	$u^2(L_{EX,8h})$	$u(L_{EX,8h})$
Unloading	6,86	2,6
Sterilization	3,60	1,9
Extraction	11,46	3,4
Clarification	8,97	3,0
Palm nuts unit	4,67	2,2
Utilities	8,99	3,0
Maintenance	20,36	4,5

Homogeneous Exposure Group (HEG)	$U(L_{EX,8h})$
Unloading	4,3
Sterilization	3,1
Extraction	5,6
Clarification	4,9
Palm nuts unit	3,6
Utilities	4,9
Maintenance	7,4

The extended, $U(L_{EX,8h})$ uncertainty, determined by the formula $u(L_{EX,8h}) = 1.65 \times u$ is calculated and recorded in the table below for each of the Toumanguie's oil mill HEG:

Table 10: Results of the extended $U(L_{EX,8h})$ uncertainty in HEG of the Toumanguié oil mill

For the measurement to be representative of a given HEG, these should comply to some statistil methods requirements. Table 11 below explicits these for Toumaguie's case.

Table 11: Minimum total measurement time specifications for effective n_G of homogeneous exposure grousp of Toumanguie's oil mill

Number of workers in the Homogeneous Exposure Group (HEG)	Minimum cumulative measurement duration to be shifted all over the HEG
$n_G \leq 5$	5h
$5 < n_G \leq 15$	5h + (n_G – 5) x 0,5h
$15 < n_G \leq 40$	10h + (n_G – 15) x 0,25h
$n_G > 40$	17h. Else the group should be fractionned

3.4.5. Final Results

The effective duration of the working day by shift in the Toumangui's oil mill was Te = 7h30 min, including a 30 min break with the shift change. The level B-weighted daily noise exposure for homogeneous exposure groups noise Toumanguié oil mill were calculated using equation (B) (2) and the results are shown in table 12 below:

Table 12: Levels of weighted daily noise exposure for homogeneous noise exposure groups of the Toumanguie's oil mill

Homogeneous Exposure Group (HEG)	Daily Exposure Level $(L_{EX,8h})$	Incertitude élargie $U(L_{EX,8h})$
Unloading	84,4	4,3
Sterilization	88,9	3,1
Extraction	91,0	5,6
Clarification	89,6	4,9
Palm nuts unit	92,0	3,6
Utilities	98,2	4,9
Maintenance	92,9	7,4

According to Jacques [1], it is generally accepted that a level of

85 dB A for 8 hours per day is the limit not to be exceeded. Estimating the "Alert coast" 85 dB(A) and "coast danger" to 90 dB(A). The proposal of the European Community was to choose a limit of 85 dB(A) as the maximum not to exceed a worker exposed to 8 hours per day level.

In the absence of clear regulations in Ivory Coast on noise, the noise level in the workplace should not exceed 85 dB for 8 hours of exposure. This daily limit exposure level is that currently at force in several European Union countries such as the United Kingdoom since 2005 [13]. From table 12 above, we notice that all HEG, except the Unloading HEG have daily exposure levels greater than 88.9 dB, which is grater 85 dB. So far the Toumanguie's oil mill offers free personal protective equipment to workers. These are hearing protectors (SNR 28) and ear plugs (SNR 17). However efforts should be keept in order to avoid noise induced deafness from Toumaguie's palm oil mill because even in Great Britain where strict regulations are enforced, there were 150 new claims for Noise-Induced Hearing Loss disablement benefit assessed in 2011 [14]. On the other hand, at this thime there was no hearing conservation program. Despite its high noise levels, no cases of occupational deafness have been reported or listed in the archives of the medical and social center of Toumanguie oil mill.

Deafness or hearing problem resulting from noise at workplace are real threats as evidenced by a Medical Research Council survey [15] in 1997-98. That survey gave a prevalence estimate of 509,000 people in Great Britain suffering from hearing difficulties as a result of exposure to noise at work. The fact that at this time, no deafness has yet been reported at Toumanguie could simply result from the fact that hearing loss induced by continius exposition to moderate level is at first unnoticiable and may takes several years to become to evident [16].

4. CONCLUSION

Most workers in the oil mill of Toumanguié (except those working at unloading) are exposed to high noise levels and are at risk of developing health problems , including hearing loss and security issues. Different homogeneous exposure groups should be immediately integrated into a hearing conservation program in addition to individual hearing protection they enjoy. Workers units receiving daily doses of 98.2 dB (A) must be supported by a health care professional in a program of hearing protection.

Given the high level of the noise exposure of workers in the palm oil mill of Toumanguié; efforts should be made to reduce the risk of deafness resulting from of exposure to noise.

Priority in the first action would be an acoustic study in order to reduce the noise to which they are exposed, either by removing the source, either acting on its propagation medium. This solution is difficult to setup and very expensive.

In this context, the use of personal protective equipment including hear protectors seems acceptable to mitigate noise. The integrated agricultural unit of Toumanguié must provide appropriate personal protective equipment for work and raise awareness of the actual bearing thereof. The hearing conservation program must be implemented and all the exposed workers should benefit of it and be followed by a health professionnal.

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