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Vibration Levels And Reported Health Symptoms Among Workers In Ubungo 1 Power Plant In Dar Es Salaam, Tanzania

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Abstract:

Background: Vibration is a common occupational hazard produced by gas fired combustion engines in electric generating power plants. Workers especially in production area (maintenance workers and Operators) are occupationally exposed to high vibration levels when performing their tasks. Therefore, workers are at risk of develop Whole Body Vibration (WBV) health symptoms.

Aim of study: The study aimed at assessing vibration levels and reported health symptoms among workers in Ubungo 1 power plant in Dar es Salaam, Tanzania.

Material and Methods: A cross section study was conducted among 70 workers exposed to vibrations in Ubungo 1 Power Plant in Dar es Salaam. Vibro-meter connected to accelerometer (SD-8205) was used to measure vibrations magnitude in engines and on walk-way floor. Structured questionnaire was used to collect information of WBV health symptoms among workers. Data were analyzed using SPSS version 20, and Chi Square used to prove the association between dependent variable and predictor variables.

Results: Majority of the study participants were male 57(81.4%) and few female 13(18.6%). Workers in production area reported to experience WBV health symptoms such as 68.2% abdominal rumbling, 63.6% abdominal pain, 52.3% low back pain, 52.3% fatigue and 43.2% headache. Vibration produced by engines during the study period ranged from 20.9m/s^2 to 26.37m/s^2 that were within the recommended levels of 27m/s^2 while vibration measured on top walk-way located 1 meter from engines ranged from 1.29m/s^2 to 2.36m/s^2 that were above the recommended Exposure Limit Value (ELV) of 1.15m/s^2. Chi square analysis has shown association between vibration levels and WBV health symptoms experience by workers such as low back pain 13(52%), abdominal pain 20(80%), sleep disturbances 7(27%), loss of balance 13(52%) and chest pain 14(56%) with statistical significant of p value <0.05.

Conclusions: Majority of workers who reported to experience WBV health symptoms were performing their tasks in high vibration workplace. Reduction of vibration by hierarchical of control and especially engineering is recommended. Therefore, Occupational health and safety department should conduct periodic monitoring of vibration in the workplace and communicate with workers through different safety signs.

Keywords: Whole body Vibration, vibration levels, Power Plant vibrations

I. INTRODUCTION

Tanzania electricity production was dominated by large hydro power plants, due to extensive droughts in the country it resulted into power supply shortages; the situation led to an active promotion of utilization of natural gas in production of electricity(Kichonge, 2018). Power plants have been one of the industries which utilize the modern technological machineries, designed and operating under automatic control systems, thus increasing its efficient and safeguarding workers

against occupational risks. However, mostly of installed machineries in power plant accompanied by different hazards including vibrations (Kanta et al, 2017). Static machinery can cause floors and work platforms to vibrate(James et al, 2003), thus vibration produced can be transferred to the floors or work platforms cause Whole Body Vibration (WBV) for workers around(Bovenzi, 2014).

WBV refers to the situation where the whole body is exposed to vibration through contact by the buttocks or feet (Dhanjee et al, 2016);WBV occurs commonly in off-road work such as in construction (Madhushanka et al, 2015) and on the road haul drivers (Neghab et al, 2016). To improve the health and safety of workers, Tanzania Environmental Management (Standards for the Control of Noise and Vibrations Pollution) (Ice, 2015)and European directive union (2002/44/EC) have establish the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibrations) (European Directive, 2006). The recommended permissible vibration action value should be less than $0.5m/s^2$ and exposure action limit should not exceed $1.15m/s^2$.

Regular exposure to WBV is associated with development of a number of adverse health consequences including low back pain (Bovenzi et al, 2017), abdominal pain, fatigue, cardiovascular disease (Dzhambov, 2016), heartburn, loss of balance, chest pain and sleep disturbance (Kamp V et al, 2015). But also, workers exposed to WBV are often subjected to a number of other risk factors that may contribute to the development of these adverse health effects. These risk factors include age (Murtezani et al, 2012),maintaining a static posture for a long period of time, or twisting of the abdomen and heavy lifting (Krajnak et al, 2018).

Ubungo 1 power plant as one of electricity producers in Tanzania, utilizes gas fired combustions engines in electricity generation. The combustion engines convert a natural gas into electricity through mechanical processes (Haga, 2011); the mechanical movement of part produced a certain vibration levels which can easily transferred to the floor surfaces. Workers in production area (maintenance and operators) mostly were exposed to WBV due to the nature of their work as a result the risk of injury from Whole Body Vibration exposure(Shehap et al, 2015).

Currently the proportional of workers in Ubungo power plant experience WBV health symptoms is not known; despite workers continue working in vibratory surface. Therefore this study will assess vibration levels and associate with reported WBV health symptoms experience by workers in Ubungo 1 power plant in Dar es salaam, Tanzania.

II. MATERIAL AND METHODS

A. RESEARCH DESIGN

A cross-sectional study design was conducted among 70 workers in Ubungo 1 power plant from July to August of 2019. It involved Operators, maintenance workers and other office workers (managers, administrative officers, supply officers, store, security and cleaners). Operators and maintenance workers were mostly involved in maintenance and mechanical repair of the gas- fired combustion engines.

B. RESEARCH AREA AND LOCATION

This study was conducted in Ubungo 1 power plant area, located at Ubungo in Dar es Salaam. It is a Gas powered Plant (Gas-fired plant), using locally available Songosongo natural gas as a source of fuel. The plant is installed with twelve (12) generating units (gas fired combustion engines) each with capacity of 8.73 MW making an average of 104 MW produced in case all the engines are in good working.

C. MEASUREMENT PROCEDURE

Whole Body Vibration measurements were assessed according to the measuring procedures outlined in International Standardization Organization, ISO 2631-1(1997), European Directive 2002. Accelerometer was connected to the vibration meter (SD 8205) was used to measure magnitude of vibration in engines. The accelerometer was attached at different points to measure vibrations. The time required for fitting and removal of the accelerometer and the data acquisition system were 10 minutes as recommend by manufacturer in order to get a correct data.

Distance between engines and work platform were measures using meter rule. Using accelerometer connected to Vibro-meter, vibration levels were measured at 1 meter on a top walk-way and at 2 meters and 4 meters on the ground level away from engines.

D. SAMPLE SIZE AND SELECTIONS

A convenience sampling was used; this was due to small number of workers present in each section in the power plant. Workers who have at least 1 year working experience were allowed to participate in the study (One year was the latency period for the effect to manifest), while workers undergone surgery was excluded in the study.

The study involved 44 workers from production section (13 operators and 31 maintenance workers) and 26 other office workers, making a total of 70 workers in the plant.

E. QUESTIONNAIRE

A semi structured questionnaire Swahili version and English version were distributed to workers for the purpose of filling some individual information such as age, profession, working experiences, health status and exposure duration, number of breakdown attended in machines and working distance from machines.

Whole Body Vibration health symptoms assessed were; Low Back pain, Sleep disturbance, Loss of balance, Chest pains, Headache, Visual Dysfunction , abdominal pain, stomach rumbling, heartburn, high blood pressure and fatigue. Workers in power plant were duly informed and were assured of confidentiality, privacy and anonymity of information provided. Only participants who provided informed consent were allowed to fill the questionnaire.

F. METHOD OF ANALYSIS

The vibration acceleration-time histories in m/s^2 obtained from the vibration meter was downloaded and entered into Microsoft Excel to obtain the weighted root mean square in m/s^2. According to the European Directive 2002/44/EC on mechanical vibration, daily vibration exposure is expressed in terms wRMS (weighted Root Mean Square (m/s^2), calculated as;

$$wRMS = Aw(T/T8) \quad (1)$$

Where Aw frequency weighted-acceleration at a time t,

T is the total daily duration of vibration exposure (hours), and T8 is the reference duration of 8 hours.

The Crest Factor (CF) is the ratio of the maximum (peak) weighted acceleration value to the weighted RMS. It is given as;

$$CF = Aw\ Peak\ /wRMS \quad (2)$$

Where CF = crest factor; Maximum Aw = highest value of acceleration (m/s^2); and wRMS = RMS average acceleration (m/s^2); CF should be less than 9 (Akinnuli et al, 2018).

The collected data were cleaned, coded, entered, and analyzed by Statistical Package for Social Sciences (SPSS) version 20 using descriptive statistics and Chi-square test at 5% level of statistical significance.

III. RESULTS

A total of 70 workers were participated in the study at Ubungo 1 Power Plant. Results showed that majority of the respondents were males 81.43% while female were 18.57%. 72.9% of participants were overweight (BMI above 35) as shown in Table 1

Characteristics	Operators (n=13)	Maintenance workers (n=31)	Other workers (n=26)
Gender			
Male	12 (92.3)	31(100)	14(53.8)
Female	1 (7.7)	0	12(46.2)
Age group (years)			
25-34	2 (15.45)	9(29)	9(34.6)
35-44	3(23.1)	9(29)	13(50)
45-60	8(61.5)	12(38)	4(15.4)
BMI n (%)			
18-25 (kg/m^2)	2(15.4)	10(32.3)	7(26.90)
> 25 (kg/m^2)	11(84.6)	21(67.7)	19 (73.1)
Education level n (%)			
Primary school	4 (30.8)	2 (6.7)	7 (26.9)
Secondary	3 (23.0)	6 (19.4)	4 (15.4)
Diploma	5 (38.5)	17 (54.8)	2 (7.7)
Higher education	1 (7.7)	6 (19.4)	13 (50.0)
Working hours n (%)			
<8 hours per day	9 (69.2)	24 (77.4)	22(84.6)
≥8 hours per day	4(30.8)	7(22.6)	4(5.4)

Table 1: Demographic characteristics of workers in Ubungo 1 power plant. Data shows number and percentage of workers n (%)

A. WHOLE BODY VIBRATION HEALTH SYMPTOMS AMONG WORKERS IN UBUNGO 1 POWER PLANT

Results indicated that majority of workers in production section were suffered with abdominal rumbling 68.2% abdominal pain were 63.6%, low back pain were 52.3%, fatigue were 52.3%, and headache 43.2% with statistical significant $p<0.05$ as shown in Table 2

WBV health Symptoms	Maintenance workers and Operators n=44	Other workers n=26	Row Total N =70	P value
Low back pain	23(52.3%)	2(7.7%)	25 (35.7)	0.000*
Abdominal pain	28(63.6)	8(30.8)	36 (51.4)	0.008*
Abdominal rumbling	30(68.2)	7(26.9)	37 (52.6)	0.001*
Nausea	8(18.2)	5(20)	13(18.6)	0.913
Heartburn	11(25)	8(30.8)	19(27.1)	0.566
Sleep disturbance	8(18.2)	3(11.5)	11(15.7)	0.461
Chest pain	20(45.5)	7(26.9)	27(38.6)	0.124
fatigue	23(52.3)	7(26.9)	30(42.9)	0.038*
Loss of balance	19(43.2)	6(23.1)	25(35.7)	0.09
Visual Dysfunction	13(29.5)	7(26.9)	20(28.6)	0.8
Headache	19(43.2)	3(11.5)	21(31.4)	0.006*
Circulatory problems (High blood Pressure	11(25)	2(7.1)	13(18.6)	0.072

Table 2: Whole Body Vibration health Symptoms experienced by workers in Ubungo 1 power Plant; Data represents number of workers and percentages, n (%)

B. GAS FIRED COMBUSTION ENGINES CHARACTERISTICS

During data collection s it was observed that, twelve (12) modern computer controlled gas fired combustion engines manufactured in 2015 were installed in a plant. Each engine has a capacity of 8.73 MW and was designed to operate on natural gas at low pressure 5 bar (73PSI). The engines were installed in two parallel halls, each hall containing 6 combustion engines each. Among those engines only nine (9) were working during data collection, the remaining were not on duties.

a. MAGNITUDE OF VIBRATION PRODUCED BY COMBUSTION ENGINES IN UBUNGO 1 POWER PLANT

The measurement were done in nine gas fired engine machines, the results showed that the maximum vibrations were $26.37+0.5\ m/s^2$ and the minimum vibration were $20.9+0.24\ m/s^2$, as shown in Figure 1.

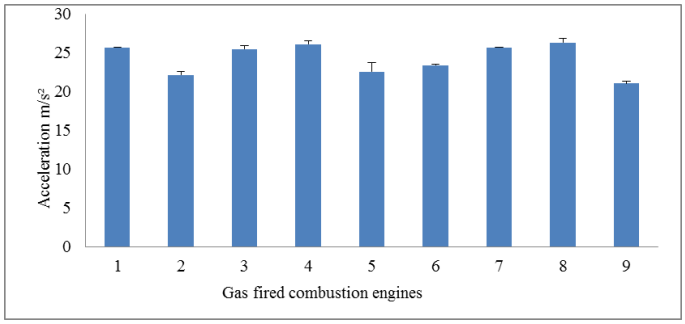

Figure 1: Vibration Magnitude for Nine Gas Fired Combustion Engines in Ubungo 1 Power Plan

b. Vibration levels on top walk-way

Vibration levels measured on top-walk way at 1 meter from vibration source, the results shows that at one meter (1m) vibration levels (wRMS) exceeded the exposure limit value of 1.15m/s2 as shown in Figure 2

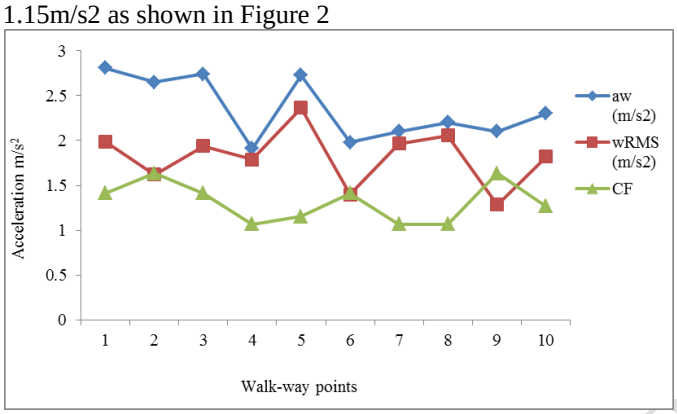

Figure 2: Vibration Exposure Levels on Walk–way, 1 Meter from Vibration Sources

c. *VIBRATION LEVELS ON GROUND FLOOR*

Vibration levels measured at 2 m from combustion engines, the result shows that the vibration levels (wRMS) were within the allowable limit, between the Exposure Action Value (EAV) and Exposure Limit Value (ELV) (0.5m/s^2-1.15m/s^2) as shown in Figure 3.

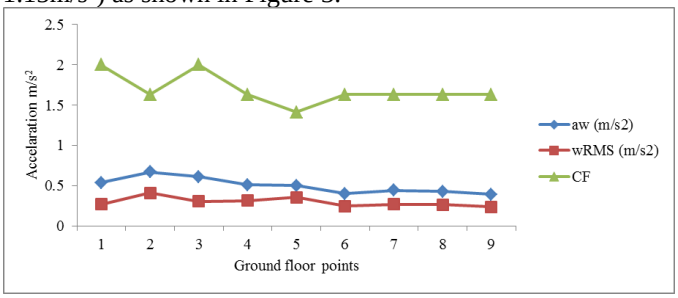

Figure 3: Vibration exposure levels on ground floor, 2 m away from vibrations sources

Vibrations levels measured at 4 meters away from combustion engines on the ground surface, and the result shows vibrations levels (wRMS) were below EAV 0.5m/s^2 as presented in Figure 4

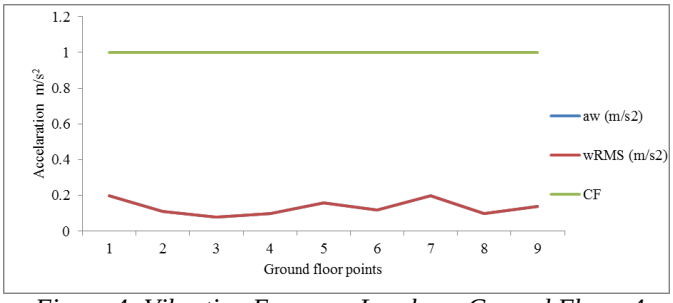

Figure 4: Vibration Exposure Levels on Ground Floor, 4 Meter away from Vibration Sources

d. ASSOCIATION BETWEEN VIBRATION LEVELS AND WBV HEALTH SYMPTOMS AMONG WORKERS IN UBUNGO 1 POWER PLANT

Using Chi square test, the results showed that workers exposed to vibration level(>1.15 m/s^2) experience WBV health Symptoms such as low back pain 52%, abdominal pain 80%, sleep disturbances 27%, loss of balance 52% and chest pain 56% and the difference are statistical significant p value <0.05 (Table 2)

WBV health Symptoms	Vibration levels ≤1.15m/s^2 n=45	>1.15m/s^2 n=25	*p*-value
Low back pain	12(26.5)	13(52)	0.034*
Abdominal rumbling	21(46.1)	16(64)	0.16
Heartburn	12(24.4)	8(36.8)	0.135
Nausea	7(15.6)	6(24)	0.385
Abdominal pain	16(35.6)	20(80)	0.00*
Fatigue	19(42.2)	11(44.3)	0.87
Sleep disturbance	4(8.9)	7(27.3)	0.035*
High blood pressure	8(18.5)	5(38.5)	0.187
Eye strain	12(26.7)	8(32)	0.63
Headache	11(24.4)	11(44)	0.09
Loss of balance	12(26.7)	13(52)	0.032*
Chest pain	13 (28.9)	14(56)	0.025*

*Table 3: Association between Vibration Levels and WBV Health Symptoms experienced by workers in Ubungo 1 power Plant; Data represents number of workers and percentages, n (%) and *p-value<0.05*

IV. DISCUSSION

Findings from the study in Table 2 shows that workers in production section (maintenance workers and operators) were suffered with low back pain 52.3% compared to 7.7% of other office workers(p<0.05). This percent is low compared to the study done in Kosovo Power Plant; workers with low back pain were 83.4% among production workers, and 61.6% among office workers (Murtezani et al, 2012). The percentage of workers who suffer digestive disorders such as abdominal pain were 63.6%, abdominal rumbling were 68.2%, heartburn were 25% and nausea were 18.6% among workers studied, and this percentage was high compared to study conducted in Parali . In that study, workers working in power plant and got some digestive problems were 14% (Kawalkar et al, 2014). This might be contributed by working environment condition

such as intermittent working in vibration workplace and elsewhere. Also 43.2% production workers suffered with headache, this is high compare to the study done in Korea which shows 11.2% were suffered with headache (Kim et al, 2017). And 52.3% of workers experience fatigue, this percentage was higher compared to the study done in Nigeria, where by the highest proportion were 37% and 40% among community exposed to vibration (Jibiri et al, 2015)(Agwu et al, 2017). The high percentages of fatigue among workers in Ubungo 1 power plant might be contributed by activities done in power plant, such as frequency maintenance of equipment which involve bending, lifting up of equipment or tighten/loosing of some parts of machines which are the common activities for workers in production area. Such a situation may lead over exhaustion of energy, and lead to the decrease in ability for muscles to produce more forces.

The magnitude of vibration produced by gas-fired combustion engine were of different range with a maximum of 26.37 $m/s^2 \pm$ 0.5 and the lowest of 20.98 $m/s^2 \pm 0.23$, according to Wartsila standard/acceptable vibration levels (producer of these gases fired combustion engines), the maximum allowed vibration level for Wartsila engine which complied with ISO 10816-6 was 27 m/s^2 (from Wartsila Machine manual). The difference between the maximum vibrations required and measured from combustion engine in Ubungo 1 power plant was $0.63m/s^2$. This means there is small difference to reach the maximum permissible limit. Operating machine at high vibration might lead to imbalance of machines due to it weariness of some parts or misalignment which can lead to breakage of machine parts(Kanta et al, 2017). Current situation in Ubungo 1 power, one of the concrete bases for placing engine machine has been broken and it is associated with high vibration produced by engines.

Furthermore, vibration levels measured at 1 meter on the top walk-way away from the vibration source, the Weighted root mean square value of the vibration were 2.36 m/s^2 for eight hour, above the vibration exposure limit value of $1.15m/s^2$ (figure 4.2), this is similar to the study done in Nigeria showed that people who working near generators at 1m were exposed to high vibration level of 6.14 m/s^2 (Jibiri et al, 2015). This vibration levels were above the recommended levels which put workers vulnerable to high health risks. It also observed that vibration on top walk-way arises from machines component connected with Engines, so vibration can easily transferred to the beams of walk-way and causes impacts. Vibration reaches ground floor have been minimized by fixing Dampers (stiffness), as a result vibration could not travel much to the ground floor

At 2m away from the gas-fired engines (figure 4.3), the observed weighted root mean square values (wRMS) was $0.62m/s^2$ maximum and $0.4m/s^2$ minimum . This was below the vibration exposure limit (ELV) of $1.15m/s^2$ as shown in Table 5. The wRMS acceleration were found to be within the recommended values, this implies that most of the workers working in this area, should take a precautions, in terms of using properly protection devices such as safety shoes so as to reduce the Symptoms.

At 4m away from vibration sources (figure 4.4), the maximum vibration level were $0.2m/s^2$. According to EU directory (Table 4.5), $_W$RMS value was below recommended Exposure Action Value of $0.5m/s^2$, this was similar to the study done in Nigeria which show that vibration was reduced with distance (Agwu et al, 2017).

During measurements, it was observed that ground vibration levels have been minimized by fixing gas fired engines with dampers, As a result vibration could not travel much through the floor, and thus the accelerometer could not sense much vibration on the ground floor.

The findings in Table 2 shows workers exposed to vibrations levels above the recommended ELV of $1.15m/s^2$, have reported WBV health Symptoms, such as low back pain 52%, abdominal pain 80%, loss of balance 52% and chest pain 56% with statistical significant of p value <0.05. These percentages were higher compared to the study done in Nigeria among the generator users workers suffer with abdominal pain were 11%, low back pain back pain 44%(Jibiri et al, 2015)(Agwu et al, 2017). This might be contributed by their nature of the work performed in the power plant and exposure time. Also the result is similar to the study done among drivers, where the bus drivers exposed to high vibration experience more health effect (Neghab et al, 2016)(Bovenzi et al, 2017)(Azenan et al,2018). 27% have shown experiencing sleep disturbances among workers exposed to vibration above the limit, similar to the study done in nuclear power plant in Japan (Marko T, 2014), this might be contributed by changing of shift during working time.

Usually occupational illness reduced performance and concentration among workers; this cause inefficiency in performance and also increase medical cost to the company and an individual.

STRENGTH AND LIMITATIONS

This is the first study conducted to assess workplace vibration levels and WBV health Symptoms among workers at power plant in Tanzania. Despite of the strength, the study has some limitations;

Logistic regression was not employed in determining risk factors associated with Whole Body Vibration health effect; this is due to limited sample size. Another limitation was study design; A cross Sectional study design was employed, which has time limit; data collection took only one week which does not reflect the whole year vibration records.

V. CONCLUSION

Majority of workers in Ubungo 1 Power Plant have reported experience WBV health Symptoms, and most of them are found to perform their duties in production section (Maintenance workers and operators). The vibrations produced by Gas Fired Combustion Engines were within the recommended vibration levels, but high vibration measured on top walk-way may be due to connection of some machines component and floor supporting surface. Regular exposure to vibration levels above the recommended limit increase the chance of getting WBV health risk among workers. Therefore workers should perform some of the activities away from vibration sources to decrease risks associated to whole body vibration.

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