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IMPACT OF OCCUPATIONAL NOISE ON THE CIRCULATORY SYSTEM OF WORKERS IN A TYPICAL FLOATING PRODUCTION VESSEL

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Abstract

This study investigates the possible impacts of occupational noise exposure on the circulatory system of workers in a typical floating, production, storage and offloading (FPSO) unit in the Niger Delta Offshore work environment in Nigeria. The VLIKE VL6708 digital sound level meter was used to measure noise levels at 2-hour interval over an 8-hour workday. OMRON-10 Series BP7450 Upper Arm Blood Pressure monitor was used to measure arterial blood pressure (systolic and diastolic) and pulse rate of work before and after exposure for 8-hour workday. Noise sampling spanned 2 weeks from 7am to 6pm daily at 2-hourly interval at workplaces grouped into 5 work activity noise sources namely; Topside, Machinery Spaces, Engine room, Accommodation deck and Helideck noise. Corresponding blood pressure and pulse rate monitoring was carried out twice per workday with a 5 hours interval on workers in different 5 groups. Results showed that mean value of noise levels obtained were 89.1 dBA (Topside), 88.9 dBA (Machinery Spaces), 89.5 dBA (Engine room), 74.7 dBA (Accommodation Deck) and 90.9 dBA (Helideck) and that there was 8.9 mmHg incremental net change in systolic blood pressure, 5.1 mmHg in diastolic pressure and 2 bpm in pulse rate, respectively, though not statistically significant ($p<0.05$). Correlation data analysis effect on systolic blood pressure and pulse rate, but both indicated weak positive correlation at $p<0.05$.

Key words; Occupational Noise, Circulatory system, Floating Production Storage and Offloading (FPSO)

Introduction

A typical floating production vessel is a floating, production, storage and offloading (FPSO) system. They are mostly employed in deep-water oil and gas production and engineering operations as a result of their comparatively low fabrication and construction cost, as well as being relatively stable and adaptable in offshore operational environment. They can either be converted from already existing tankers with good and suitable structural design or directly purpose-built. It is this intended use in offshore operational environment that constitutes the key determinant in their design (Olunloyo & Osheku, 2012). However, these identifiable characteristics predispose FPSO as choice assets for offshore oil and gas exploitation and production operations, where they undergo high level hydrodynamic loading. The dynamic forces at play and other necessary engineering and operational activities within this superstructure, collectively constitute a significant source of occupational noise hazard. Turbulent flare discharge from the flare stack, the topside gas turbine, automated systems on the topside modules, main crane, essential and emergency electrical generators, heating, ventilation and air conditioning (HVAC) systems, compressed air discharge at blast nozzles, and noise from crew change helicopter operations on the FPSO are the primary noise sources.

Excessive noise is one of the most common workplace hazards and long-term exposure to high noise levels has been linked to a variety of negative auditory and non-auditory health impacts (CDC, 2017). The auditory system is mostly impacted, which may result in tinnitus, noise-induced hearing loss (NIHL) and transient threshold shift (TTS) (Nelson et al., 2005), all of which have become well-known in vast literature. Non-auditory impacts associated with hazardous noise emission in the workplace may include changes in physiology such as increased heart rate and blood pressure (circulatory system parameters), adrenaline and cortisol hormone secretion (Basner et al., 2014). As a result, occupational noise is a significant physical risk factor across a wide range of industries, from small to large scale (Goelzer et al., 2001), including manufacturing, textiles, printed materials, metal goods, pharmaceuticals, timepieces, and mining (Nelson et al., 2005).

Salameh (2005) worked on Effects of Occupational Noise Exposure on Blood Pressure, Pulse Rate, and Hearing Threshold Levels of Workers in Selected Industrial Plants in Jenin City, Palestine. In this work, he evaluated the relationship between occupational noise level with arterial blood pressure (systolic and diastolic), pulse rate and hearing threshold levels for workers in industrial plants in Jenin region by a random sampling of 15 plants to represent the different noise levels. The blood pressure, pulse rate, and hearing threshold levels at different frequencies were measured before and after exposure to noise for a period of six to eight hours. Wrist blood pressure monitor and dosimeter were used for blood pressure and noise level measurements respectively. The study results showed a strong positive correlation (Pearson Correlation Coefficient) for most of the measured variables. Systolic blood pressure mean value increased by 4.5 mmHg, while the diastolic blood pressure mean increased by 5.1 mmHg and the pulse rate mean value increased by 9.1 beats/minute, after exposure to occupational noise. The hearing threshold levels also showed decrease in mean value of (1.2 to 5.8) decibels

In a study, which aimed at Investigation of the Effect of Occupational Noise Exposure on Blood Pressure and Heart Rate of Steel Industry Workers, Zamanian et al. (2013) conducted a cross-sectional study, involving 50 workers selected from a steel company in Fars province, Iran who were exposed to varied noise levels (85, 95, and 105 dB) noise levels for a 5minute period. Blood pressure and heart rate measurements using Beurer BC16 pulse meter were carried out before and after the exposure to occupational noise. Result of study demonstrated no significant difference in the blood pressure and heart rate before and after exposure of participants. However, there was increment in systolic blood pressure compared to measurements before exposure. This difference did not show significance statistically ($P > 0.05$). Similarly, participants' heart rate reduced compared to measurements before exposure to noise and again, this difference was statistically insignificant ($P > 0.05$). No significant difference was established in blood pressure and heart rate after acute exposure to 85, 95, and 105dB noise levels. Findings of this study were in agreement with those of the previous investigations conducted, as no significant difference was detected in blood pressure and heart rate before and after acute exposure to 85, 95, and 105dB noise levels. However, this study was not conducted on a typical FPSO offshore work facility.

Rutkowski and Korzeb (2021) in their study Occupational Noise on Floating Storage and Offloading Vessels (FSO) evaluated the potential impacts of being subjected to high level noise measured on 1st generation (30+ years old) Floating Storage and Offloading (FSO) vessel in offshore work environment. Occupational noise level measurements were obtained with the use a Bruel & Kjaer type 2270 sound level meter. Study results showed that high noise levels were produced in offshore workplace, particularly on FSOs. It showed that most of the high noise areas were not clearly marked and personnel were unaware of hazardous noise levels. Some recreational facilities onboard offshore vessels are located not adequately faraway from high noise source. Hearing protection must be donned on all helicopter flights and workboat trips. Additionally, other work activities should not contribute to increased noise exposure. Unprotected workers and the others in the work surroundings of the blasting process, as well as blasting cabinet operators were at risk of excessive noise exposure

These empirical studies focused on occupational noise and its effect work environment, blood pressure and heart rate specifically in Iran and Palestine, but no empirical study has focused on FPSO in Niger-delta, Nigeria. Consequent on these empirical studies reviewed, it became pertinent to also evaluate the far-reaching impacts of occupational noise emission on the circulatory system of offshore workers on a typical Floating, Production, Storage and Offloading (FPSO) vessel, operating in the oil and gas rich Niger Delta Province of Nigeria. Therefore, the aim of this study is to investigate the possible impact of occupational noise emission on the circulatory system of offshore workers on a typical Floating, Production, Storage and Offloading vessel, operating in the oil and gas rich Niger Delta Province of Nigeria

Materials and Methods

Satellite and current positions of the studied FPSO are shown in Figure 1 at coordinates 3.99126° N / 7.29072° E, currently sailing under the flag of Nigeria in the Gulf of Guinea. Typically, a FPSO facility is a system that receives deep-seated fluids, mostly crude oil, water, etc. from subsea reservoir rock formations through associated riser piping networks. The collected fluids normally are separated into different components like crude oil, natural gas, water and associated impurities within the topsides production modules onboard. The crude oil is stored in large marine or cargo tanks within the FPSO and offloaded onto oil shuttle tankers that go to the oil and gas market or for future refining in onshore facilities. Some of the operational facilities in a typical FPSO layout include: Topside Process Systems, Utility Systems and Miscellaneous facilities, the hull, marine systems, cargo storage tanks, Offloading facilities and Accommodation quarters. Others, non-topside are: the Engine room, Machinery Spaces and Helideck. However, the noise producing mechanical equipment on the Topside are associated with processing facilities, which include large gas turbines (power generation units), air and marine compressors (cargo deck aft), oil and gas compressors, air exchange cooler fans, HVAC ventilation fans on power generation module and ultra-high pressure (UHP) diesel-driven engine machinery for water-jetting and wet abrasive blasting continuous fabric maintenance works. In the accommodation quarters are the Air Handling Units, Ancillary living quarters' HVAC System, Inert Gas Generator room, etc. The Machinery Space is another high noise level area with grinders, cooler fans, freshwater generators, HVAC chiller generators, cargo and ballast hydraulic pump motor, essential service generator and seawater cooling pumps. The boiler (normal and offload operations) which is located in the Engine room, as well as the mechanical workshop and fabrication space and steering gear pump room etc. are significant high noise sources in the engine room. The main source of high noise in the Helideck is the Sikorsky S-76 Helicopter during landing, idling and offtake routine operations

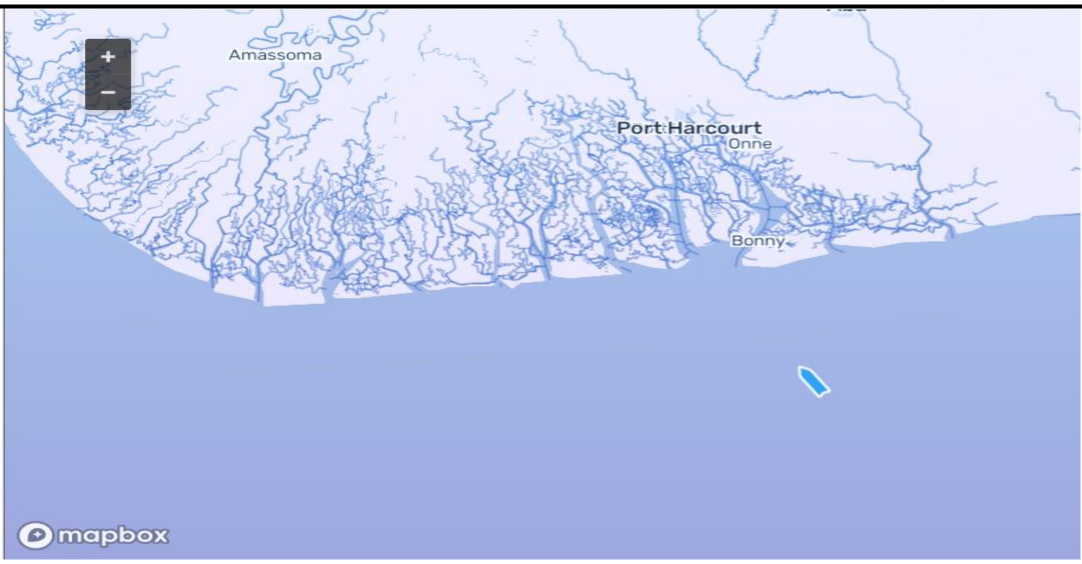

Figure 1, Current offshore position of FPSO. (Source: Shipfix, 2021)

2.2 Study Population

This study was conducted on a typical FPSO in the Gulf of Guinea section of the Niger Delta offshore, with a population of one hundred (1000) personnel on board (POB). The sample size for this study is 285 and was calculated using Taro Yamane's 1973 formula for sample size calculation

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

where n is the minimum sample size required for the study, N is the Population under study, and e is the margin of error set as 5% at 95% confidence level.

2.3 Sampling Technique

Sampling frame was categorized into five (5) work activities or noise sources of a typical FPSO, covering Topside, Machinery Space, Engine room, Accommodation Deck and Helideck Purposive sampling was used for this study with proportional allocation for gender, age bracket, marital status, number of years on current job and minimum of eight (8) hours per day work duration. Other criteria for inclusion in the study were: being physically and psychologically healthy (not having any heart condition), not smoking, not using alcohol, not taking hypnotic drugs and not working in shifts.

2,4 Methods of Data Collection

Two instruments/devices were used for data collection. The VLIKE VL6708 digital sound level meter (SLM) device was used to measure noise level in the FSPO while the OMRON 10 Series BP7450 Upper Arm blood pressure (BP) monitor was used to measure arterial BP (systolic and diastolic), as well as pulse rate of exposed workers.

The essential components of the sound level meter are: microphone, amplifier and LCD digital display, which shows readings in decibels. Additional descriptive information about the sound level meter device include compliance with IEC 60651 – 1979 Type 2 (Class 2) and NSI S1.4 - 1983 Type 2. The Upper Arm Blood Pressure monitor comprises a dual LCD display that allows for immediate comparison of current and past readings; pre-formed, easy wrap, inflatable arm cuff, which fits arm-size range from 9 inches to 17 inches in circumference. For noise measurement, Areas of interest were grouped into work activity noise source(s). Respective noise levels in dB (A) were measured and number of exposed personnel recorded. Noise level measurement was conducted for 2 weeks; sampling was carried out from 8am to 6pm, to account for daily workday duration and data collected at every 2 hours interval before respective tea breaks and lunch break. SLM was positioned at about 1.2m above deck/floor level and at a practical position with the most noise impact on personnel. The five (5) work activity noise sources selected were: Topside, Machinery Space Deck, Engine room (boiler operations), Accommodation Deck and Helideck. Arterial Blood Pressure (systolic and diastolic), and pulse rate of exposed workers were measured on the left upper arm of each participant twice a day using the upper arm BP monitor; first, in the morning before work begins and thereafter, the second measurement taken at a 4 to 5 hour period into each workday.

Instruments used were checked and calibrated pre and post use and when required. Standard sound of 94 dB was used to calibrate SLM microphone. Operating environmental conditions for sound level meter were maintained within these specifications: less than 2000m specified elevation; less than 80%RH relative humidity and temperature range of 0 – 40 degrees Celsius. Upper arm blood pressure monitoring device has been clinically validated for use.

2.5 Methods of Data Analysis

The data obtained were analyzed using IBM SPSS statistical Software Version 22 , Paired T-test was used to compare the mean of variables before and after exposure to noise and ANOVA (Analysis of Variance) was used to compare statistical difference among means of more than two groups where the statistical difference is significant and null hypothesis was rejected it p-value is less than confidence value otherwise null hypothesis was accepted

Results and Discussions

3.1 Occupational Noise levels in studied FPSO

Table 1 present the occupational noise levels in the studied FPSO. The results show heightened values above the NIOSH Recommended Exposure Limits (REL) of 85 dBA for 8 hours workday duration for Topside (89.1 dBA), Machinery space deck (88.9 dB(A)), the Helideck (90.9 dBA) and the Engine room (89.5 dBA). Comparatively, the Accommodation deck (74.7 dBA) containing the offices, washroom, rest cabins, galley etc. falls into the <80 dB(A) noise level band.

The results revealed that high noise levels are evident in a typical first generation FPSO. The major sources of noise on the FPSO includes the large gas turbines and production modules on the topside; the machinery space with air handling units, fresh water generators, circulating pumps; engine room boiler and associated operations; accommodation machinery, galley, washroom equipment; the helideck, with noise also from helicopter landing and takeoff operations. However, the topside, the machinery space, engine room and helideck noise level mean values all fall into ≥ 85 dBA noise band rating, exceeding the NIOSH recommended exposure limit (REL) of 85 dB(A) over an 8 - hour average known as total weighted average (TWA). Noise levels at or above this threshold are considered harmful according to Centre for Diseases and Control. This study aligned with work of Rutkowski and Korzeb (2021) who also evaluated noise level at different section **of** Storage and Offloading Vessels (FSO) to ascertain areas with different level of noise and they revealed that high noise levels were produced in offshore workplace, particularly on FSOs.

Table 1 Occupational Noise levels in studied FPSO

Work Activity Noise Source/Category	Noise Level Range [dB(A)]	Mean Value of Noise level equivalent, L_{eq}[dB(A)] (± Standard Deviation)	Number of workers surveyed around source
Topside	68.4 – 116.2	89.1 ±13	23
Machinery Space	67.2 – 124.4	90.9 ±17	11
Engine Room (ER)	65.9 – 110.9	89.5±12	15
Accommodation	45.8 – 100.7	74.7±17	28
Helideck	74.5 – 107.2	90.5 ±7	8

3.2 Blood Pressure (systolic and diastolic) and Pulse rate before exposure

Mean values of systolic Blood Pressure, diastolic blood pressure and pulse rate before exposure of workers to noise levels less than 80 dB(A) were 115.4±8.2 mmHg, 79.3±3.4 mmHg and 83.3±2.9 bpm respectively (Table 4.2). Also, before exposure to noise level greater than 85 dB(A), mean value readings were 118.1±5.0 mmHg, 77.5±2.6 mmHg and 87.7±4.0 bpm for systolic, diastolic and pulse rate respectively in the topside, machinery space, helideck and engine room in the studied FPSO.

Table 2 Systolic Blood Pressure, diastolic blood pressure and pulse rate before exposure of workers to noise

Source Noise Level/NIOSH REL in dB(A)	Mean Systolic Blood Pressure (± Standard Deviation) (mmHg)	Mean Diastolic Blood Pressure (± Standard Deviation) (mmHg)	Mean Pulse rate (± Standard Deviation) (bpm)
< 80 dB(A)	115.4 (±8.2)	79.3 (±3.4)	83.3(±2.9)
≥ 85 dB(A)	118.1(±5.0)	77.5(±2.6)	87.7(±4.0)

3.3 Blood Pressure (systolic and diastolic) and pulse rate after exposure

The mean value of systolic BP, diastolic BP and pulse rate after exposure of workers noise level less than 80 dB(A), in the Accommodation deck area were 121.3±1.9 mmHg, 81.0±2.0 mmHg and 87.6±1.9 bpm respectively (Table 4.3). In addition, after exposure to noise level greater than 85 dB(A), computed results were 129.9±4.8 mmHg, 85.3±3.4 mmHg and 87.5±2.7 bpm for systolic, diastolic and pulse rate respectively in the Topside, Machinery space, Helideck and Engine room in the studied FPSO.

Table 3 Blood Pressure (systolic and diastolic) and Pulse rate after exposure

Source Noise Level / NIOSH RE in dB(A)	Mean Systolic Blood Pressure (± Standard Deviation) (mmHg)	Mean Diastolic Blood Pressure (± Standard Deviation) (mmHg)	Mean Pulse rate (± Standard Deviation) (bpm)
< 80 dB(A)	121.3 (±1.9)	81.0 (±2.0)	87.6 (±1.9)
≥ 85 dB(A)	129.9 (± 4.8)	85.3 (±3.4)	87.5 (± 2.7)

3.4 Net change of blood pressure (systolic and diastolic) and pulse rate before and after exposure

Net change in systolic Blood pressure, diastolic blood pressure and pulse rate before and after exposure are revealed in Table 4. The net change of systolic Blood pressure before and after exposure was 8.9mmHg while that of diastolic blood pressure before and after exposure was 5.1mmHg and 2 bpm net change in pulse rate before and after exposure. Net level change in mean values of systolic and diastolic blood pressures where

8.9 mmHg and 5.1 mmHg respectively, while that of the pulse rate was insignificant at 2 bpm. This suggests that the topside, the machinery space, engine room and helideck are high noise work areas and also constitute significant workplace hazard, being a ‘stressor’ with a potential to impact the circulatory system of associated workers over prolonged exposure. It acts in a similar mechanism as other stressors, where it could cause alterations in the body’s response that might be subtle over a long time, resulting in occupational health problems, often referred to as ‘stress illnesses. This result showed mixed agreement with work of Salameh (2005) whose study showed Systolic blood pressure mean value increased by 4.5 mmHg, while the diastolic blood pressure mean increased by 5.1 mmHg and the pulse rate mean value increased by 9.1 beats/minute, after exposure to occupational noise. The hearing threshold levels also showed decrease in mean value of 1.2 to 5.8 decibels

Table 4. Net change of blood pressure (systolic and diastolic) and pulse rate before and after exposure

	Systolic Blood Pressure (mmHg)	Diastolic Blood Pressure (mmHg)	Pulse rate (bpm)
Before Exposure	116.7	78	85.5
After Exposure	125	83.1	87.5
Net Change	8.9	5.1	2

3.5 Correlation between occupational noise levels and arterial blood pressure (systolic and diastolic) and pulse rate before and after exposure

Correlation data analysis and values (Table 4.5) showed significant (2-tailed) effect on systolic blood pressure (dependent variable) with (r = 0.482, p = 0.009) Pearson Coefficient, r value of 0.482^{**} and on Pulse rate (dependent variable) with (r = 0.374, p = 0.004) Pearson Coefficient, r value of. 374^{**}. Howbeit, both indicated a weak positive correlation at p<0.05. Statistical data analysis showed significant (2 tailed) effect on systolic blood pressure and pulse rate, although both circulatory system parameters indicate weak positive correlation (P<0.05). The observed increase in systolic BP is in agreement with Zamanian et al., (2013), where there was incremental net change in SBP after acute exposure of participants to 85, 95 and 105 dBA noise levels. However, that difference was not statistically significant (P>0.05), compared to the weak positive correlation (P<0.05) in the study. These results also contradict the work of Salameh (2005) whose results showed a strong positive correlation (Pearson Correlation Coefficient) for most of the measured variables whereas in this case it is only systolic BP that has strong positive correlation.

Table 5 Correlation between occupational noise level and arterial blood pressure (systolic and diastolic) and pulse rate before and after exposure

Noise Level	Variable	Mean (±Std) Before Exposure	Mean (±Std) After Exposure	Pearson Coefficient	Significant (2-Tailed)
	Systolic BP	115.4 (±8.2)	121.3 (±1.9)	$.482^{**}$	**.009**
< 80 dBA	Diastolic BP	79.3 (±3.4)	81.0 (±2.0)	**- .178**	**.364**
	Pulse rate	83.3 (±2.9)	87.6 (±1.9)	**- .076**	**.701**
	Systolic BP	118.1(±5.0)	129.9 (±4.8)	**- .006**	**.967**
≥ 85 dBA	Diastolic BP	77.5 (±2.6)	85.3 (±3.4)	**.181**	**.178**
	Pulse rate	87.7 (±4.0)	87.5 (±2.7)	$.374^{**}$	**.004**

*Correlation is significant at the 0.05 level (2-tailed)

Conclusions

High occupational noise levels are produced in a typical FPSO offshore workplace and well above their statutory Recommended Exposure Limits (REL) ≤85 dBA. The impact of high noise level can result in a variety of occupational health conditions including auditory effect like noise induced hearing loss (NIHL) and non-auditory physiological alterations occasioned by increase in circulatory system parameters like arterial (systolic and diastolic) blood pressure and pulse rate. net increase in these parameters, although overall they were not statistically significant and also showed weak positive correlation across independent variables.

Occupational noise is no doubt a stressor, capable of causing hormonal, autonomic and behavioural change connected to fear and stress, that can cause cardiovascular health diseases like hypertension, ischaemic heart diseases (IHD) and stroke, although the direct path through which they are caused are not yet known.

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