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Quantification of Noise and Air Quality Risks at a Crude Oil Flow Station

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1. INTRODUCTION

The oil and gas industry has grown to become an economic contributor to Nigeria's economy, which is also a large employer of the labor force in Nigeria[1]. However, there have been concerns over the potential health and environmental impacts of crude oil production in Nigeria[2]. Though resources from the oil and gas industry sustain the Nigerian economy, activities in the oil industry pose potential risks especially to the frontline workers who might be exposed daily[3]. Occupational hazards refer to workplace factors, processes, circumstances, material substances; that have the potential to cause harm and

thus pose a threat to the health and safety of workers in all occupations [4]. It presents in the form of occupational health and safety hazards. Additionally, environmental hazards could mean any situation or state of events that poses a threat to the surrounding natural environment and adversely affects the health of an individual [5].

It is, however, important to distinguish exposures within the oil and gas facilities from exposures outside these facilities, which lies in the confines of the environment. Globally, a lot of attention has been devoted to the environmental impact of oil and gas activities, with little attention shown on the impact on frontline workers in the occupational domain. Occupational and Environmental hazards could broadly be classified as physical, ergonomic, chemical, biological, mechanical, and psychosocial hazards [6]. Ergonomic hazards in the oil and gas industry include manual handling, lifting, lowering, pulling, pushing, confined workspace access, narrow walkways, prolonged awkward posture and poor body mechanics [7]. Physical hazards in the oil and gas industry include ionizing and non-ionizing radiation, noise, whole-body vibration and vibrating hand-tools, inclement weather [7]. Chemical hazards include carcinogens like benzene, various acids, hydrogen sulfide, crude, mud component of drilling fluid, welding or cutting fumes as well as irritant, toxic, corrosive and sensitizing substances[8]. Biological hazards could be legionella, food-borne pathogens, to name but a few[7]. While these lists are in exhaustive, they constitute potentially harmful risks to frontline oil and gas workers. Exposure scenarios and categories of causative activities in the oil and gas industry that generates most of these hazards include seismic operations, exploration and drilling, production, preventive and corrective maintenance, processing of hydrocarbon, transportation of the unfinished and finished product, de-commissioning of installation etc[9]. During these activities, employees could further be exposed to varieties of hydrocarbon waste, process materials and substances in the work environment that portend significant occupational risk[9].

Relatedly, workers are exposed to unintentional gas leaks from oil and gas activities arising from equipment leaks, process venting, evaporation losses, disposal of waste gas streams (e.g., by venting or flaring), accidents and equipment failures, methane

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emissions from wastewater handling, methane from industrial wastewater and sludge streams, and nitrous oxide from human sewage. These hazards pose a variety of significant health and safety risks[10]. Crude oil and natural gas composition vary slightly, according to reservoirs; however, it possesses consistent toxicological properties. Chemicals such as polycyclic aromatic hydrocarbons (PAHs) and benzene are toxic components of crude oil and are a source of concern[8]. These chemicals along with others found in crude oil are volatile and capable of moving from the oil into the air. Once airborne, they can blow over the sea and creeks for kilometers, reaching communities far from the source of emission. Though they may be perceived as hydrocarbon odors; workers and people living in neighboring communities will be exposed to crude oil and natural gas aerosols in the air[8]. Differences in exposure will occur based on location, work and personal activities, age, diet, use of protective equipment, and other factors. Exposure to a combination of toxic chemicals, especially if they are capable of causing harm to organs in the body, increases the potential for adverse health effects[8, 10].

Gas flares releases a significant amount of greenhouse gases and causes the release of particulate matter, sulfur dioxide, nitrogen dioxide, and carcinogenic substances such as benzo(a)pyrene, dioxin, benzene and toluene, which can have severe health effects on unprotected frontline workers [1]. The paucity of information on the impact of hazards associated with oil and gas activities on frontline workers spurred the interest for this study. This study thus set out to examine and quantify the noise levels and amount of air pollution within crude oil flow stations in the Niger Delta region of Nigeria as representative hazards. The findings could be used as a guide to improve health and safety practices as well as drive further research within the stated research scope.

II. METHODOLOGY

The study was carried out in a crude oil flow station, an installation located along the Escravos River in the Delta State of Nigeria. Though the facility is about 200 meters from the Escravos village, it is also surrounded by numerous fishing settlements and villages. Geographically, the installation lies between latitudes 4° and 6° north of the equator and longitudes 5° and 9° East of the Greenwich Meridian [11]. The installation is bounded on the North by the Escravos river, on the South by Escravos village, on the East by a mangrove swamp and numerous fishing settlements located about 80 meters away and on the West by the Nigeria Atlantic Ocean continental shelf. Accessibility to the site is by sea and air. The facility was chosen for the study because of the dense activities of oil exploration and production with the potentials for

hazard generation in and around the installation. The flow station receives crude oil from surrounding well-heads through numerous flow lines and rises to the separators; which separate the crude, gas and water before pumping out through an export pipeline to a distant gathering facility.

The materials used in this study includes Casella Micro dust pro (Dust Monitor), and Multi-Gas Meter for air quality analysis, CEL-485 (serial number 109776) Sound Level Meter and CEL-282 calibrator for noise survey.

To assess the risk of gas flare and fugitive emissions within the facility, air quality measurement was conducted. Air sampling with measurement of suspended particulate matter and air quality profiling was done using Casella Micro dust pro (Dust Monitor) and Multi-Gas Meter respectively, with readings taken from 14 sites in the facility environment. The Multi-Gas Meter was used to assess for Sulfur Oxides (SO_x), Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Carbon dioxide (CO₂), and Volatile organic compounds. The dust monitor uses the principle of near forward light scattering to measure dust particle concentration. The air quality meter uses the principle of extractive sampling and ultraviolet fluorescence [12].

Area noise measurements were undertaken in 40 locations within and outside the facility using a CEL-485 (serial number 109776), which was calibrated using a CEL-282 calibrator (serial number 3/10921327). Noise measurements as 30 seconds LAeqs(averages) and frequency band analysis were undertaken at 20 locations approximately 5 meters apart on a grid within the facility running at 75-80% of its capacity on the day of noise survey; and 20 locations outside the facility (in the administrative and accommodation buildings). Purposive sampling technique was adopted in the selection of the 40-measurement locations within the facility. After putting on the hearing protection devices (Ear-muffs and Ear-plugs), the sound level meter (SLM), was switched on and turned to the high measurement mode. The measurement trigger was activated with the meter microphone pointed at the point of interest and noise level was measured and recorded. The sound level meter was calibrated at Casella measurement laboratories, the UK using a standard acoustic calibrator (94dB, 110 Hz sine wave). A-weighting for the general noise sound level was chosen. The instrument was held in the hand of the author and the microphone pointed at suspected noise sources. The MAX and MIN (maximum, minimum) modes were selected and the sound pressure level was displayed at their maximum and minimum readings. The average reading was then taken for each of the forty locations within and outside the facilities. Data was inputted with the Microsoft Excel spreadsheet (2007 version) and then imported into the Statistical Package for Scientific Solutions (SPSS) version 21.0 (statistical software package) for analyses. Tables and

graphs were used for data presentation and means were used for data expression.

III. RESULTS

In this study, assessment of the noise levels within and outside the Escravos flow station gave the following results. All twenty locations measured within

the facility had high noise levels ranging from 76.8 - 111.7 dB(A). Also, all twenty measured locations outside the facility revealed low noise levels ranging from 32.6-69.5 dB (A). These details are shown in Tables 1 and 2 below.

Table 1: Noise measurement within the facility

SN	Locations	LAeq dB (A)	Lmax dB (A)
1	Pump 1(Operational)	89.5	90.9
2	Pump 2(Operational)	90.0	94.1
3	Pump 3(Operational)	90.6	90.7
4	Pump 4 Station	85.1	87.1
5	Pump 5 Station	85.0	86.5
6	Turbine Unit	86.0	87.4
7	Caterpillar Generator	111.7	112.3
8	Air compressor	88.3	89.2
9	Surge Vessel 2	85.2	86.4
10	Saver pit	78.6	83.5
11	Low Pressure Separator 1	83.8	88.3
12	High Pressure Separator 1	84.1	87.0
13	Test Separator 1	80.2	81.8
14	Surge Vessel 1	82.8	84.9
15	Metering skid	82.6	84.2
16	Manifold area	82.2	83.0
17	Low Pressure Separator 2	83.4	84.0
18	High Pressure Separator 2	80.8	81.6
19	Test Separator 2	81.4	82.1
20	Mustering Area	76.8	80.8

Table 2: Noise measurements outside the facility

SN	Locations	LAeq dB (A)	Lmax dB(A)
1	Kitchen	69.5	70.9
2	Laundry	66.0	74.1
3	Accommodation Room	46.6	50.7
4	Recreation	45.1	55.1
5	Reception	45.0	56.5
6	Team leaders Office	41.0	53.4
7	Operations Office	42.7	44.3
8	Mechanical Office	41.3	49.2
9	Beach Masters Office	42.2	44.4
10	Clinic	38.6	43.5
11	Boat Men Office	39.8	44.3
12	Maintenance Office	34.1	37.0
13	Camp Boss Office	44.2	45.8
14	Electrical Office	42.8	44.9
15	Instrument Office	32.6	34.2
16	Workshop	42.2	43.0
17	Station Attendant Office	53.4	54.0
18	Tool Pushers office	45.8	51.6
19	Location Planner Office	51.4	52.1
20	Sewage treatment Room	46.8	50.8

Air quality analysis showed that respective parameters (Particulate Matter, Oxides of Sulphur, Oxides of Nitrogen, Carbon Monoxide, Carbon Dioxide, and Volatile Organic compound) exceeded the normal

limits provided by the Directorate of Petroleum Resources of Nigeria. This is shown in Table 3. Particulate matter (SPM) gave the highest observed levels. This is shown in Figure 1.

Table 4: Air quality analysis around the facility

Parameters	DPR Limit	Sample 1	Sample 2	Sample 3	Average values
Oxides of Sulfur (SOx) (ppm)	0.05	0.06	0.05	0.06	0.14
Oxides of Nitrogen (NOx) (ppm)	0.07	0.08	0.08	0.09	0.25
Carbon Monoxide (CO) (ppm)	8	8	9	10	9
Carbon dioxide (CO ₂) (ppm)	N/A	28.7	30.1	30.5	29.8
Particulate matter (SPM) (μg/m ³)	60 - 90	200.0	300.0	360.0	287
Volatile Organic Compounds (VOC) (ppm)	N/A	30	30	30	30

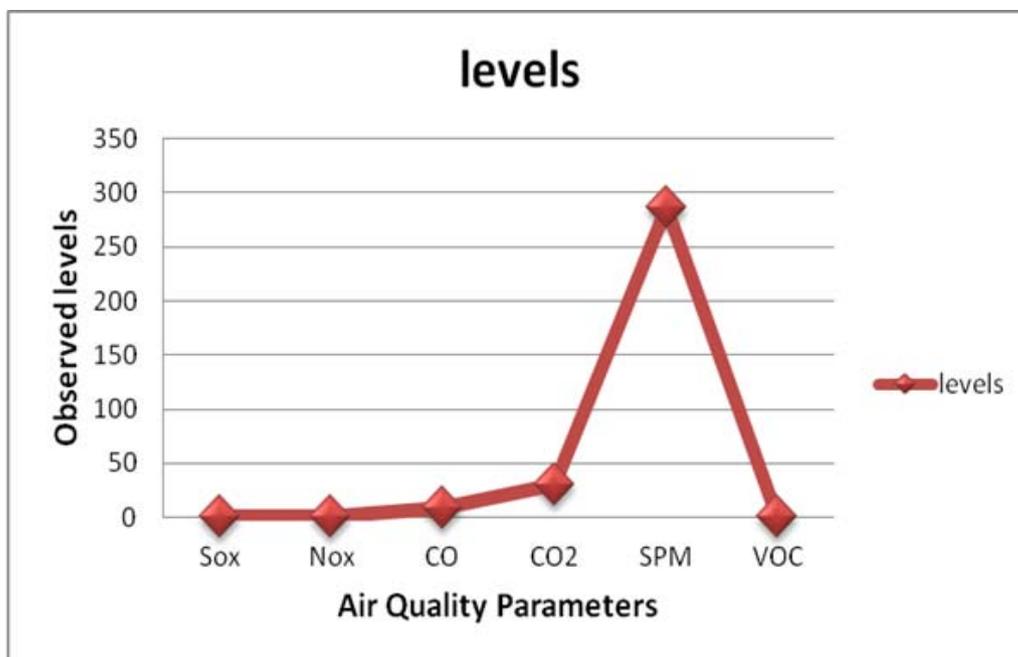


Figure 1: Graphical distribution of air quality parameters within the facility

IV. DISCUSSION

As seen in this study, the mean levels of noise and particulate matter concentrations exceeded permissible exposure limits. Thus noise and gaseous hydrocarbon emissions potentially constitute sources of occupational hazards to workers in this study, which agrees with similar findings of other authors [3]. In the oil and gas industry, temporal threshold shift could result from prolonged unprotected exposure to high noise levels[3]. This study showed that noise levels at the generator house and pump house exceeded normal permissible limits. This is in agreement with other studies that have shown that the sources of noise during the production phase in the oil industry include generator and turbine, compressor and pumps,

producing wells, flow dynamics, and occasionally flaring[3]. While the primary impact of noise is on the workers who work in the facility daily for two weeks before embarking on two weeks' time-off, these condary impacts from noise could be localized disturbance to wildlife, recreationists, and residents. The risk of exposure to noise sources within the facility can be reduced to As Low as Reasonably Practicable (ALARP) by using the Hierarchy of Controls, [3].

These controls include the elimination of noisy equipment, substitute noisy equipment with other equipment that makes less noise, isolates equipment with noise absorbent materials, applies engineering controls to equipment that cannot be eliminated or substituted to reduce noise, apply procedural controls to reduce duration or magnitude of exposure, and

provision of personal hearing protection. Furthermore, it is necessary that a comprehensive hearing conservation program (HCP) is put in place for all personnel exposed to noisy environments exceeding 85dBb (a). This program will include noise survey of suspected workstations, develop and deploy noise maps at facility entrances, identify exposed personnel, mandatory training on noise-induced hearing loss, mandatory annual audiometry, mandatory use of hearing protector, and compliance enforcement [13].

The presence of atmospheric pollutants poses an occupational health risk to the workers and environmental health risks to residents that reside near the generating facility. Common atmospheric pollutants encountered in different oil and gas sites include sulfur oxides (SO_x), oxides of nitrogen (NO_x), hydrogen sulfide (H_2S), carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen cyanide (HCN), Ammonia (NH_3), particulate matter, heat radiation and noise [14]. Three months' average air quality analysis revealed Suspended Particulate Matter (SPM) concentration of $287 \mu\text{g}/\text{m}^3$, which is above the Federal Ministry of Environment (FMENV) limit of $250 \mu\text{g}/\text{m}^3$. Depending on the chemical composition and size of the SPM, prolonged exposure renders workers and inhabitants of host communities vulnerable to chronic respiratory disease; impairment of visibility, sensory irritation, worsens hay fever, and allergies; stunts the growth of vegetation; and leads to decreased visibility [14]. SPM is composed of small particles that are suspended in the air and settles to the ground slowly [15].

The most common sources of particulate matter from oil and gas operations are dust from the separation of crude oil and associated water, and engines used to power machinery at oil and gas facilities. Particulate matter release into the atmosphere can also occur during venting and flaring operations [16]. The analysis further revealed Volatile Organic Compounds (VOC) concentration of 30ppm, which is well above the FMENV limit of 20ppm. Volatile Organic Compounds (VOCs) are carbon-containing substances that readily evaporate into the atmosphere. Crude oil is a densely saturated carbon-containing substance, with Benzene and Toluene being the most common VOC in the oil and gas industry. They have the capacity to adversely affect lung function etc [14].

Also, Oxides of Sulphur (SO_x) concentrations were 0.14 ppm which lies above the FMENV limit of 0.01- 0.1ppm. Exposure to SO_2 at concentrations above 5.00 ppm could stimulate bronchio-constriction (as seen in asthma), aggravation of respiratory disease, impairment of pulmonary functions, irritation of eyes and pulmonary tract and reduced growth in plants. Sulfur dioxide reacts with other chemicals to form particulate pollution, which can damage the lungs and cause respiratory diseases; heart conditions, and premature death [16-18]. Oxides of Nitrogen (NO_x) concentrations

were 0.25 ppm, which is above the DPR limit of 0.07ppm and FMENV limit of 0.04-0.06ppm. The health impacts from NO_x include respiratory problems, heart conditions, and lung damage [16]. Carbon Monoxide (CO), concentration was 9ppm which is below the DPR limit of 8ppm. Prolonged and excessive exposure to an ambient accumulation of CO could bring about the formation of carboxy-hemoglobin and prevent oxygenation of blood, leading to suffocation and consequent death. It inhibits the blood's ability to carry oxygen and can cause dizziness, unconsciousness, and even death [14].

Several environmental challenges associated with petroleum exploration and production activities exist and are varied and multifaceted. Some of these problems include generation and disposal of aqueous effluent of oily waste, combustion of products of gas flaring at gathering stations and high environmental noise levels. One of the environmental problems associated with crude oil exploration and exploitation is linked to gas flaring [14]. The Department of Petroleum Resources (DPR) in 2002 produced a revised version of its Environmental Guidelines and Standards for the Petroleum Industries in Nigeria (EGASPIN). This guideline is in addition to other existing regulations on industrial standards promulgated by the Federal Environmental Protection Agency, 1991 (now Federal Ministry of Environment) to improve environmental management performance in Nigeria. This notwithstanding, several oil installations still violate the regulatory limits [14]. Environmental contaminants from gas flaring include a number of oxides of Nitrogen, Carbon and Sulphur, particulate matter etc [14,19]. The flares also contribute to acid rain, which causes the corrosion of aluminium roofs, soil acidification etc. Acidic soils have been described as having lost its and this could be harmful to crops. [20-21].

V. CONCLUSION

From the findings of this study, it can thus be concluded that the activities of the flow station contribute to noise and air pollution which could have potentially deleterious effects on workers' health and the environment. It is thus recommended that apart from applying the usual methods of reducing noise effects, innovative ways to reduce the noise generated be utilized to reduce noise pollution around oil and gas facilities. Adequate technologies to stop the flaring practices should be developed by utilizing the Associated Gas for electricity generation using gas turbines and re-injecting the Associated Gas into the oil field to enhance crude oil recovery. Gas is being increasingly seen as a viable source of energy to speed up development needs in Africa. In Nigeria, though gas is wasted through flaring activities, creating harmful air pollutants and biomass, it is still the mainstay of cooking

and other heating. Thus, attention should be paid to the reduction of gas flaring and channeling such gas for small-scale utilization such that it benefits the local communities.

Author Contributions: The author developed the study design and survey instrument, trained the research staff, and was involved in data analysis and manuscript preparation. He was also involved in data collection, data analysis and interpretation of the results.

Conflicts of Interest: The author declares no conflict of interest.

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