International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518

Evaluation of Noise Levels and its Effects on Workers at Indorama Petrochemical Complex, Eleme, Nigeria

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Abstract

This study is aimed at evaluating the emitted noise levels from the process plat at the Indorama Petrochemical Company Ltd, Nigeria. Noise levels and Geographical Position measurements were undertaken with the TES 1350 Sound Level Meter and a suitable Geographical Positioning System (GPS). Mapping of the measured noise levels were undertaken using the emitted noise levels and geographical positions of the measurement points. The result of the noise level measurement showed that the emitted noise levels range between $105.3dBA$ within the process plant and $32.2dBA$ at radial distance of 50.0m from the plant. These measured noise levels were higher than the level specified by the provisions of the applicable regulation. The responses from the exposed workers indicate that the emitted noise negatively impacts their physiological and psychological health conditions. Similarly, the result of the Chi Square analysis, at .05 level of significance, shows significant association between the emitted noise levels and the responses of the workers with a calculated Chi Square value of 27.07 against a critical value of 18.31. Following the results of this study, it is recommended that the provisions of the applicable legislation should be adequately enforced to ensure that appropriate technical measures are put in place to have reduction in the emitted noise levels and/or reduction in exposure time.

Key Words: Evaluation, Noise, Noise levels, Effects, Workers, Petrochemical, Complex

Introduction

Noise has been identified as one of the physical environmental stressors that affects the health and general well-being of the populace around urban and industrialized cities around the world ''[2], [9], [6], [17], [8]'' The noise levels around these industrialized environments results majorly from anthropogenic activities ranging from urbanization, transportation to various forms of industrial activities ''[10], [19], [20], [17]'' which generate sounds that are inherently loud, unpleasant and unexpected. The fact was corroborated by Joshi et al, (2003) through a study that indicated that the rapid growth in technology in the developing countries has made noise pollution one of the major threats facing the environment with the cost of its reduction in the future becoming insurmountable.

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Noise is generally defined as unwanted sounds that are irritating, distracting, intrusive, interfering as well as physically and internally painful and very annoying in nature ''[22]''. Noise also causes serious environmental pollution problems through destructions of environmental properties, ''[3]''. Generally the effects of continuous exposure to extensively high noise levels are of physiological and psychological dimensions. The physiological characterizations of the effects of noise comprise of acoustic trauma, temporary threshold shift and permanent hearing problems. Atmaca [3] illustrated the negative effects of exposure such as blood pressure increase, heart beat accelerations, appearance of muscle reflexes and sleep disorders as part of the physiological effects, and the more common psychological outcomes of exposure to include annoyance, stress, anger, concentration disorders as well as difficulties in perception. The Sound Pressure Level from a typical noise source was expressed by [4] as

$$L_p = 20log_{10}\frac{P}{P_{Ref}} \quad (1)$$

While the intensity of the sound, defined as the average acoustic energy transmitted through a unit area per unit time, was similarly expressed as

$$I = \frac{W}{4\pi R^2} \quad (2)$$

International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518

With P, being the sound pressure of the source and P_{Ref}, the reference sound pressure ($2x10^{-5} N/m^2$); W is the acoustic power of the source and R radial distance from the sound source.

A particularly serious area of concern in the study of environmental noise is the noise levels emanating from industrial machines and processes as an unwanted consequence of their expected outputs. Scientists have attempted to study occupational noise exposure in different industries and the effects of such exposure on human's health. Anjorin [[2]] focused on the sources of such occupational noise and illustrated the various noise and vibration emitting equipment and operations within the industrial environment to include fluid flow in pipes and piping systems, combustions processes associated with furnaces, impact operations involving the use of punch processes, motors, power generating plants, electro-mechanical devices, unbalanced rotating shafts, gears, pumps and compressors. The generally high noise levels emitted by the operations and activities around these industries pose serious concerns to world organisations and researchers. For instance, the World Health Organisation stated that 4-5 million people (12-15% of the workforce) in Germany are exposed to hazardous noise levels, [23]. Al-Dosky [1], Stansfeld and Matheson [21] similarly stated that exposure to high noise levels around factories will result to non-auditory negative effects like headaches, dizziness, , disturbance of the mind, nervousness, stress, speech interferences and insomnia while other researchers reported exposure to relatively high noise levels for longer period of time will lead to severe auditory effects such as temporary hearing loss and permanent hearing defects ''[18], [24], [13]''.

Petrochemical processing involves utilisation of natural gas from crude oil and coal for the production of petrochemical products such as plastics, rubber, fibres, solvents and detergents. The raw materials for petrochemical production process, according to Chaudhuri [7], are in the forms of pure hydrocarbons separated and converted to desirable by-products, including surfactants, solvents and polymers through several production stages categorized as feedstocks, intermediates and finished products during which petrochemical processes such as catalytic cracking and catalytic reforming. The catalytic cracking and catalytic reforming processes results in the production of benzene, toluene and xylene which forms the major raw materials for the production of petrochemical production. Olefins, which are very essential in the petrochemical production process, are cracked gases (ethylene, propylene, butylenes and acetylenes) produced from thermal cracking of ethane, propane, butane and naphtha. Thermal; cracking is essentially a pyrolysis process involving heating of these hydrocarbon mixtures in metal tubes inside furnaces in the presence of steam at temperatures that thermally decomposes these hydrocarbon molecules. Olefins are reacts with a variety of hydrocarbons and non-hydrocarbon chemicals to generate varieties of other products such as vinyl chloride, ethylene glycol, neoprene and ethylene oxide. These varieties of petrochemical products are achieved through constructions of group of plants using a network of noise-emitting equipment equipment/machinery/tools such as pumps, compressors, HVAC systems, electric motors and other types of noisy apparatus.

Studies, of different forms and nature, have been undertaken to investigate, assess, evaluate and characterize noise form petrochemicals and other industrial operations and had come up with results which indicate that emitted noise levels are usually higher than the regulatory limits. For instance, Nwali and Agunwamba [15] studied the impact of noise on the staff, third parties and residents/host communities of the Eleme Petrochemical Company Ltd (EPCL) now known as Indorama Petrochemical Company Ltd (IPCL), Nigeria, and came up with a results that indicate that workers of this organisation are exposed to noise of very high levels. Chagok et al, [25], undertook measurements of sound pressure levels in some industries in Jos, Nigeria, and similarly assessed the attitudes of the workers towards the emitted noise. The results obtained showed that the emitted noise was steady-state, broadband and continuous in nature and has an equivalent continuous Time Weighted Average (TWA) sound level of 85dBA and above. The attitude assessment results also show a strong positive correlation between the objective and subjective variables. Boateng and Amedofu [5] evaluated noise levels around processing, mining, oil and gas, manufacturing and construction industries in Zimbabwe and concluded that a high percentage of industrial employees were exposed to noise levels above85dBA. Kisku and Bhargara [14] evaluated the major sound sources around a thermal plant and obtained results which indicated that the lowest average noise levels of 79.37dBA was found in the control room with the highest average noise levels of 95.91dBA obtained around the fans, while compressors generate the second highest noise level of 89.98dBA. Chagok et al [25] similarly quantified noise pollution from industrial noise at two selected processing and manufacturing industries in ondo state, Nigeria, and obtained results which show that

International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518

regulatory noise limit values were exceeded around almost all the machines.

The various expositions on the negative impacts of noise especially noise from industrial installation and the need to undertake a review of noise levels in the study area to serve as confirmation or otherwise of previous studies, and the need for comparison with applicable noise regulation [16] necessitated this study.

Materials and Methods

The Sound Pressure Levels were measured with the aid of the TES-1350A Sound Level Meter within the plant (0.00m) and at radial distances of 5.00m, 10.0m, 15.0m, 20.0m, 25.0m, 30.0m, 35.0m, 40.0, 45.0m and 50.0m away respectively. The Sound Level measurements were taken at heights of 1.5m above normal ground [11]. The sound level meter was held steadily as far away from the body as possible and far from hard reflecting surfaces during the measurements. The meter function selector was set on 'slow' and the weighting network set on 'A' for the dBA scale reading.

Contour maps of the measured noise levels at each of the radial distances were also drawn to give a pictorial distribution of the noise levels by taking measurements of the emitted noise level and the geophysical positions at the centre of the noise processing plant with the use of a Geographical Positioning System (GPS). Measurements of the noise levels and geographical positions were repeated at radial distances of 5.0m, 10.0m, 15.0m, 20.0m, 25.0m, 30.0m, 35.0m, 40.0m, 45.0m and 50.0m away from the process plant. The combined noise level and geographical positions established within the plant and at radial distances away were then joined up to form a contour map of the emitted noise level.

The Exposure-Impact Evaluation (EIE) involved the use of well-structured questionnaires to contract, casuals and main staffs of the safety, process and maintenance/utility department and all other workers that within and around the expansive process plant. Three Hundred and Ninety Eight (398) questionnaires were issued to these staff members to elicit response on the effects of the emitted noise level on their physiological and psychological well-being. Specifically, the questionnaire items were premised on evaluating the effects of noise on stress, tinnitus/hearing problems, cognitive impairment, sleep disturbances and cardiovascular disorder. The questionnaires were issued to workers who have spent between 2 to 5 years working within and around the process plant. Some of the respondents completed the questionnaires without assistance while others were assisted by the researcher to enable them have proper understanding of the items so as to avoid misunderstanding of the items, incomplete responses and non-return of the questionnaires. The questionnaires were analyzed using descriptive statistics such as mean, standard deviation (SD) and coefficients of variability (CV) while the chi-squared (χ^2) test was utilized to test for associations between responses and the effects of the emitted noise levels. The smaller the CV values, the more the coherence in the responses and vice versa.

Results and Discussions

The results of the noise level measurements and their corresponding Geographical Positions as well as those of the noise level mapping at radial distances are as shown in table (1) and figures (1) and (2). The measured noise levels range from 105.3dBA within the plant, 96.7dBA at 5m, 88.9dBA at 10m, 81.3dBA at 15m, 74.7dBA at 20m, 67.3dBA at 25m, 60.8dBA at 30m, 54.2dBA at 35m, 47.3dBA at 40m to43.1dBA at 45m. The results show that the noise levels within the plant to which the workers are exposed exceeded the National Environmental (Noise Standards and Control) Regulation, 2009 by the National Environmental Standards Regulations and Enforcement Agency (NESREA) permissible noise level of 90dBA for an 8hr working period. There is a high possibility of developing some psychological and physiological health conditions due to continuous exposure to these high noise levels.

International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518

TABLE 1
SOUND LEVELS And GEOGRAPHICAL POSITIONS At THE INDORAMA PETROCHEMICALS COMPANY

Distance (m)	Geographical Position		Sound Level $dB(A)$
	North	East	
0.00	N 04^0 50′ 53.80″	E007^{0}08′33.30″	105.30
5.00	N 04^0 50′ 58.30″	E007^{0}08′ 37.50″	96.70
	E007^0 08′ 33.30″	N04^0 50′ 53.80″	
10.00	N 04^{0}51′ 03.10″	E007^{0}08′ 41.90″	88.90
	E007^0 08′ 33.30″	N04^0 50′ 53.80″	
15.00	N 04^0 51′ 07.50″	E007^{0}08′ 46.30″	81.30
	E007^0 08′ 33.30″	N04^0 50′ 53.80″	
20.00	N 04^0 51′ 11.90″	E007^{0}08′ 50.70″	74.70
	E007^0 08′ 33.30″	N 04^0 50′ 53.80″	
25.00	N 04^0 51′ 16.60″	E007^{0}08′ 55.40	67.30
	E007^0 08′ 33.30″	N 04^0 50′ 53.80″	
30.00	N 04^0 51′ 21.10″	E007^{0}08′ 59.90″	60.80
	E007^0 08′ 33.30″	N 04^0 50′ 53.80″	
35.00	N 04^0 51′ 25.70″	E007^{0}09′ 04.30″	54.20
	E007^0 08′ 33.30″	N 04^0 50′ 53.80″	
40.00	N 04^0 51′ 30.20″	E007^{0}09′ 07.90″	47.30
	E007^0 08′ 33.30″	N 04^0 50′ 53.80″	
45.00	N 04^0 51′ 34.90″	E007^{0}09′ 12.40″	43.10
	E007^0 08′ 33.30″	N 04^0 50′ 53.80″	
50.00	N04^0 51′ 39.30″	E007^0 09′ 16.90″	32.20
	E007^0 08′ 33.30″	N 04^0 50′ 53.80″	

The measured noise levels were similarly mapped using the provisions of the relevant regulations [16] as shown in figures (1) and (2). The mapped noise levels reveal pictorially that noise levels of 105.3dBA to 87.0dBA from within the plant to about 10m from the plant are highly hazardous; 86.0dBA to 88.9dBA at distances of 15m to 25m are potentially hazardous due to continuous exposure while levels below 60.0dBA from distances 30m and beyond are safer to the exposed workers.

International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518

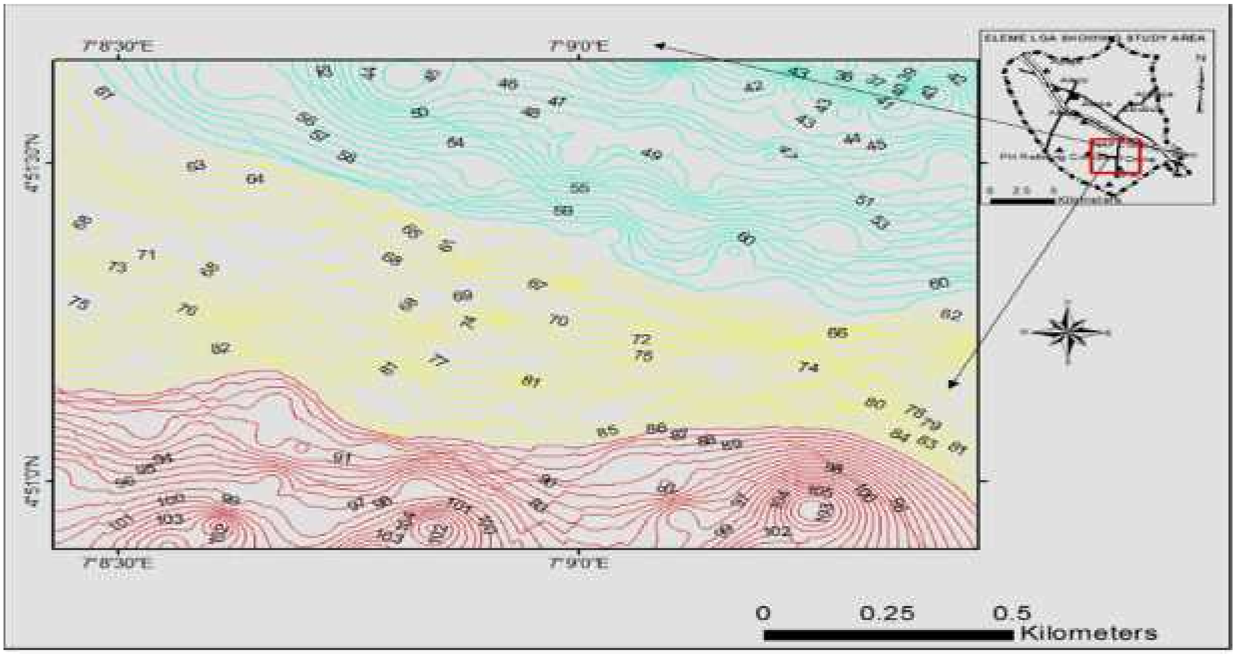

Fig (1): Gridded Map of the Measured Noise level around the Plants

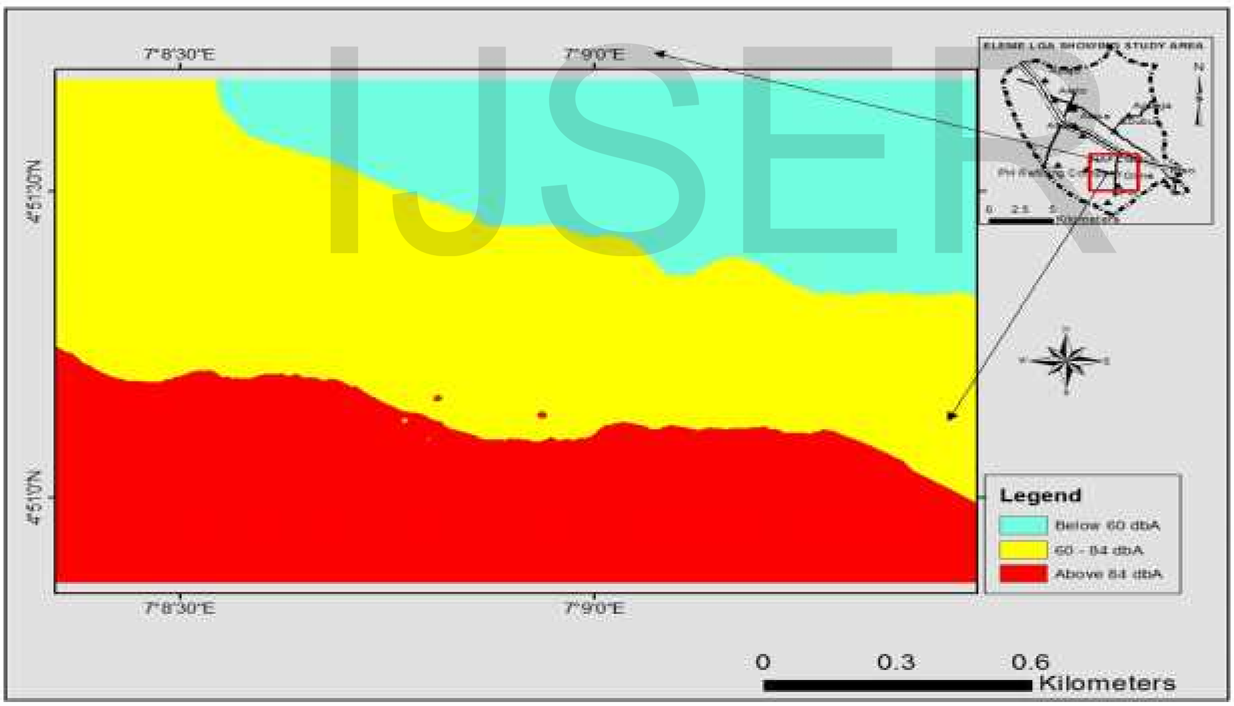

Fig. (2): Ungridded Map of the Measured Noise Level around the Plant

The ranges of values obtained from the Exposure-Impact Evaluation (Appendix) indicate that the emitted noise has some physiological and psychological effects on the health of the workers. These effects were shown by the range of values obtained for the mean and coefficients of variability for each class of effects considered to result from the emitted noise levels. Specifically, mean values between 2.74 and 2.83 and coefficient of variability values between 0.38 and 0.40 were obtained from responses on the impact of the emitted noise on cardiovascular health; means values between 2.74 and 2.92 and coefficient of variability values between 0.35 and 0.41 obtained on the impact of the emitted noise on sleep disturbance; mean values of 2.72 and 2.89 and coefficient of variability values between 0.37 and

International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518

0.42 obtained on the impact of the emitted noise on cognitive impairment; mean values of 2.80 and 2.91 and coefficient of variability values between 0.35 and 0.39 obtained on impact of the emitted noise on tinnitus/hearing problem; while the responses on the impacts of the emitted noise on stress has mean values ranging between 2.81 and 2.87 and coefficient of variability values between 0.37 and 0.40 respectively. The range of values obtained for the coefficients of variability show consensus in the response.

Similarly, the result of the chi Square (x^2) analysis (table 2) show significant association between the emitted noise level and the response of the exposed workers with a calculated x^2 value of 27.07 at .05 level of significance as against a critical value of 18.31.

TABLE 2
CHI SQAURE ANALYSIS OF THE RELATIONSHIP BETWEEN MEASURED NOISE LEVEL AND THEIR RESPONSES AT IPCL

	Outcome						
Dept	Stress	Tinnitus/ Hearing Problem	Cognitive Impair.	Sleep Disturb	Cardiov. Disorder	No Effect	Total
Safety	13 (15.27)	03 (5.54)	04 (3.69)	14 (15.88)	10 (4.56)	05 (4.06)	49
Process	47 (60.13)	27 (21.82)	17 (14.55)	62 (62.56)	22 (17.94)	18 (16.00)	193
Maintenan.	64 (48.60)	15 (17.64)	09 (11.76)	53 (50.56)	05 (14.50)	10 (12.93)	156
Total	124	45	30	129	37	33	398

$$\chi^2_{10} = 27.07 \alpha = .05\ \chi^2_{critical} = 18.31$$

The results of this study clearly show that the emitted noise levels from the process plant in this petrochemical complex is higher than the regulatory requirement of 90dB for an 8 hour working period per day. The workforce exposed to this high noise levels are at risk of developing noise-induced hearing problems and other associated psychological health problems from prolonged exposure. The provisions of the NESREA's National Environmental (Noise Standards and Control) Regulations, 2009 should be adequately enforced to ensure reduction in exposure period and/or reduction in the noise level. Adequate strategies geared towards ensuring continuous use of the appropriate Personal Protective Equipment (PPE) and creating of awareness about the adverse effects of noise among the workers should be established.

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International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
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International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518

APPENDIX

TABLE 3:

RESPONSES ON THE IMPACT OF PLANT NOISE ON CARDIOVASCULAR DISORDER AT THE INDORAMA PETROCHEMICALS COMPANY

S/ No	Statement	SA (4)	A (3)	D (2)	SD (1)	CR	N	$\bar{X}$	SD	CV
1.	Exposure to Plant/generator/vessel noise causes dizziness, nausea or vomiting	138	121	73	66	1127	398	2.83	1.08	0.38
2.	Exposure to plant/generator/vessel noise for longer period sometimes results to numbness and weakness in the arm	131	119	82	66	1111	398	2.79	1.07	0.39
3.	Continuous exposure to plant/generator/vessel noise sometimes increases the risk of confusion or disorientation.	123	122	78	75	1089	398	2.74	1.09	0.40
4.	Long-term exposure to plant/generator/vessel noise result in difficulty in comprehension	138	125	63	72	1125	398	2.83	1.09	0.39
5.	Continuous exposure to plant/generator/vessel noise increases the risk of High Blood Pressure.	131	119	71	77	1100	398	2.76	1.11	0.40

TABLE 4

RESPONSES ON THE IMPACT OF PLANT NOISE ON SLEEP DISTURBANCE AT THE INDORAMA PETROCHEMICALS COMPANY LTD

S/ No	Statement	SA (4)	A (3)	D (2)	SD (1)	CR	N	$\bar{X}$	SD	CV
1.	Exposure to plant/generator/vessel noise reduce the restorative power of sleep	129	118	68	83	1089	398	2.74	1.12	0.41
2.	Continuous exposure to plant/generator/vessel noise increases the risk of acute and chronic sleep restriction.	128	126	68	76	1102	398	2.77	1.10	0.40
3.	Exposure to plant/generator/vessel noise increases the risk of chronic sleep disturbance.	132	129	72	65	1124	398	2.82	1.07	0.38
4	Continuous exposure to plant/generator/vessel noise increases the risk of arousal,	138	125	67	68	1129	398	2.84	1.08	0.38

International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518

	autonomous responses and body movement while asleep.									
5.	Long-term exposure to plant/generator/vessel noise increases risk-taking behaviours due to poor signal detection	143	132	70	53	1161	398	2.92	1.03	0.35

TABLE 5
RESPONSES ON THE IMPACT OF PLANT NOISE ON COGNITIVE IMPAIRMENT AT THE INDORAMA PETROCHEMICALS COMPANY

S/ No	Statement	SA (4)	A (3)	D (2)	SD (1)	CR	N	$\bar{X}$	SD	CV
1.	Exposure to plant noise causes distraction and loss of concentration	128	118	63	89	1081	398	2.72	1.14	0.42
2.	Exposure to plant noise on a continuous basis causes dissatisfaction and disappointment	139	123	61	75	1122	398	2.82	1.11	0.39
3.	Continuous exposure to plant noise increases the risk of depression	141	117	71	69	1126	398	2.83	1.09	0.39
4.	Exposure to high level plant noise on a continuous basis causes increased stress and tension.	144	126	68	60	1150	398	2.89	1.06	0.37
5.	Exposure to Plant/generator/vessel noise leads to loss of concentration and cognitive function deterioration.	139	129	58	72	1131	398	2.84	1.09	0.38

TABLE 6
RESPONSES ON THE IMPACT OF PLANT NOISE ON TINNITUS/HEARING PROBLEM AT THE INDORAMA PETROCHEMICALS COMPANY

S/No	Statement	SA (4)	A (3)	D (2)	SD (1)	CR	N	$\bar{X}$	SD	CV
1.	Exposure to plant/generator/vessel noise makes me perceive constant roaring, hissing or ringing even after leaving the workplace.	135	122	67	74	1114	398	2.80	1.10	0.39
2.	Exposure to plant/generator/vessel noise makes it difficult for me to	142	132	71	53	1159	398	2.91	1.03	0.35

International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518

	listen to or hear low level sounds.									
3.	Exposure to plant/generator/vessel noise makes me have pain in one or both ears.	139	126	68	65	1136	398	2.85	1.07	0.38
4.	Exposure to plant noise makes me pressure or fullness in one or both ears	137	131	63	67	1134	398	2.85	1.07	0.38
5.	Exposure to plant/generator/vessel noise causes a loss of hearing for several hours or more after exposure to the noise.	141	129	62	66	1141	398	2.87	1.07	0.37

TABLE 7
RESPONSES ON THE IMPACT OF PLANT NOISE ON STRESS AT THE INDORAMA PETROCHEMICAL COMPANY LTD

S/No	STATEMENT	SA (4)	A (3)	D (2)	SD (1)	CR	N	$\bar{X}$	SD	CV
1.	Exposure to plant/generator/vessel noise increases my heart rate.	138	122	63	75	1119	398	2.81	1.11	0.40
2.	Exposure to plant/generator/vessel noise makes me breathe faster.	137	130	71	60	1140	398	2.86	1.05	0.37
3.	Exposure to plant/generator/vessel noise makes me sweat faster than normal.	141	121	78	58	1141	398	2.87	1.06	0.37
4.	Exposure to plant noise makes me have difficulty concentrating on mental tasks.	132	118	75	73	1105	398	2.78	1.10	0.39
5.	Exposure to plant/generator/vessel noise makes me feel more nervous.	140	131	61	66	1141	398	2.87	1.07	0.37
6	Exposure to plant/generator/vessel noise makes me more forgetful, confused and disorganized.	138	131	65	64	1139	398	2.86	1.06	0.37

International Journal of Scientific & Engineering Research, Volume 8, Issue 12, December-2017
ISSN 2229-5518