NOISE POLLUTION STUDIES OF PORT HARCOURT REFINERY, PART - 1: THE SPATIAL VARIATIONS AND DISPERSION

BY

IFY L. NWAOGAZIE, PhD, MNSE
AND
I.C. OWATE2, Ph.D,

1. DEPARTMENT OF CIVIL ENGINEERING,
2. DEPARTMENT OF PHYSICS
UNIVERSITY OF PORT HARCOURT,
P.M.B. 5323 PORT HARCOURT

NIGERIA

ABSTRACT

The noise pollution studies undertaken at the Port Harcourt Refining Company, PHRC, Nigeria in 1993 were performed in two stages. The first stage which forms the basis of this paper involved field surveys and identification of noise sources, spot readings of noise levels at 1.0 meter from source and spatial measurements along selected routes for estimate of dispersion rates. About 300 noise sources were identified and subsequently grouped in terms of equipment type as: 47% air cooler/fans, 37% pumps, 6% compressors and 10% others. Spatial measurements covered 2.9 kilometers of distance and 94 point locations for spot readings. Analysis of data revealed that two average rates of noise dispersion of 0.052 and 0.062 dB (A) per meter are representative of the study area. Generated noise levels within PHRC are well dispersed. Also, three broad classifications of the "status conditions" of the operating equipment performance are possible based on the concept of the "positive aspects of noise". The first, second and third classes are those wherein the age and/or use affect equipment performance minimally, reasonably and adversely, respectively. And a fault is likely for the second and third classes.

KEYWORD Noise pollution, noise dispersion rates, the positive aspect of noise

1. INTRODUCTION

The ability of man to make and detect sound offers him the opportunity to communicate and receive valuable information from the environment, namely; sound alarm, music, radio, TV broadcast and others.. Noise is an aspect of sound which is not pleasurable. It may be taken herein as unwanted or extraneous sound from such sources as industrial machinery, airplanes, trucks, pumps, turbines generators, stem traps, and others.

Noise generated from industrial use of machines and equipment, a case of the Port Harcourt Refining Company, PHRC should be differentiated from those of the community. Major sources of community noise are highway traffic, aircraft, construction work, and roadside workshops. Other sources include distribution transformer, railway trains, factories from which noise escape to the surrounding areas.

On the noise studies more emphasis is usually placed on the negative effects, that is, the pollutional aspects than the positive aspects (as is presented in Section 4.3). Noise can keep our senses on edge and thus, can prevent us from relaxing. How can our mental powers control this insult to our bodies, is the question? Noise can result into deafness over a long period of time. Also, as an insidious pollutant, damage is usually long range and permanent, yet it is certainly the pollutant of least public concern and perhaps the least understood (except for radioactivity) (Vesilind & Peirce, 1983)

Interest in noise control studies in Nigeria is only recent. And this may be attributed to the current guidelines and standards for environmental Pollution by the Federal Environmental Protection Agency, FEPA (1991). It is envisaged that if proper monitoring and en-

forcement of the guidelines on permissible noise exposure limits are carried out, a great deal of compliance on the part of the industrial establishments will be achieved. Infact, in 1993 Elf Petroleum Nigeria Limited financed a noise pollution abatement study for its Obagi flowstation (Gazems, 1993a) and also, Port Harcourt Refining Company, PHRC for its premises (Gazems, 1993b).

In many studies of noise pollution, emphasis may be placed on the source, path and/or receiver (Kuronen, 1988 and Gazems, 1993b). The source is the point of noise generation while the path is the route along which the noise propagates to the receiver. Noise pollution can also be studied transiently for a given point or spatially along a given route or path. For the transient noise, data are analyzed statistically by ranking and plotted for "percent of time equal to or greater than" versus noise level which gives rise to the estimate of noise pollution level, NPL (Gazems, 1993b)

Estimates of noise decay rates or dispersion is possible along a given route and this forms the basis for noise pollution forecasting at selected locations beyond the point of noise generation. Essentially, this later approach forms the basis of this paper.

2. BASIC CONCEPTS IN NOISE POLLUTION STUDY

2.1 Conceptual definitions & Units of measurement

Noise as an aspect of sounds is taken as a transfer of energy. It travels through a medium such as air without a transfer of mass. During the process of transfer, air molecules oscillate or move back and forth and the small displacement of air molecules creates the pressure waves. If the air molecules oscillate at a
frequency, f, and the noise (sound) travels at a velocity, v, the, the following relation defines the wave-length, l:

$$l = \frac{v}{f} \qquad (1)$$

where:

l = wavelength, m

v = velocity of sound in a given medium, m/sec

f = frequency, cycles/sec or Hz

Frequency and amplitude are two basic parameters that describe noise. Amplitude is expressed as "Noise Level, NL" and if it is plotted against time for a pure noise (noise with only one frequency) the wave produces a sinusoidal trace. The amplitude of a noise wave (pure or dirty) is measured in units of pressure, N/M^2. The range of pressure waves which human ears can detect are 2×10^{-5} to 2×10^{5} N/M^2. This range appears large and inconvenient, thus, giving rise to the use of decibels (dB).

Decibel is not a unit of anything but a logarithmic ratio of two pressures. The noise level is thus defined by a ratio of two pressures, one being a reference pressure (Vesilind & Peirce, 1983), that is

$$NL\ (dB) = 20 \log_{10} (P/P_o) \qquad (2)$$

Where:

NL (dB) = Noise level, in dB;
P = Pressure of noise wave, N/M^2; and
P_o = Some reference pressure, taken as the threshold of hearing, 2×10^{-5} N/M^2

Measurement of noise level is made with a sound level meter, consisting of a microphone, amplifier, a frequency weighting circuit (filters) and an output scale. The weighting network filters out specific frequencies to make the response more characteristic of human hearing. Three scales (A, B, and C) have become internationally standardized. Scale A is a good approximation of human response for not very loud noise. For very loud noise, the scale C is a better approximation. However, scale B fits in-between scales A and C. Because the use of multiple scales in ordinances, regulations or decrees in noise control will complicate issues, scales other than A are seldom employed (Vesilind & Peirce 1983).

2.2 Noise as a pollutant

The Federal Environmental Protection Agency, FEPA (1991) defines a pollutant as any substance introduced into the environment that adversely affects the usefulness of a resource. Noise will pass the above definition on account of the following (Ezenwa, 1985; and Gazems, 1993).

(i) It causes annoyance and irritation (a psychological effect)
(ii) It interferes with speech communication, also may reduce output and efficiency
(iii) It causes distinction and auditory fatigue which appears in the 90 dB ranges;
(iv) It causes masking effect, which involves the decrease in the perceptibility or intelligibility of a sound when other noise is present;
(v) It causes startled emotion produced by sudden high intensity pulse of sound affecting the automatic nervous system;
(vi) It affects the cardio muscular system by increasing or decreasing the rate of heart beat;
(vii) It affects the performance of psycho motor tasks. Also, it impairs vigilance excepting for repetitive and routine jobs and
(viii) It accelerates the presbycousis process, that is, impairment of hearing acuity with age. Generally acuity, decreases with age. Presbycousis appears from the age of 30 onwards and becomes noticeable after the age of 40. It is more marked and rapid in its onset depending on the amount of noise exposure and individual susceptibility factors.

3. FIELD SURVEY & DATA COLLECTION

3.1 Spot Readings at Noise Sources:

The field survey involved site visits of the Refinery premises, physical identification of the existing sources of noise generation, and some interactions with the officers incharge of process plants, power Plant and Utilities, etc. Spot readings of noise levels from all noise sources (operational during the period) were taken at 1.0 meter from source. A total of three hundred noise sources were identified during the survey and subsequently grouped in terms of 'types of equipment' as follows: air coolers/fans 47%, pump 37%, compressors 6% and others 10%. In this grouping, a total of ten noise producing equipment were isolated and their corresponding ratings noted (Table -1)

The rating of noise sources as low, moderate, high and very high is based on the exposure limits recommended by Federal Environmental Protection Agency, FEPA (1991). Ninety decibels or less corresponds to 8 hours exposure limit per day and is rated herein as moderate. Beyond this critical value of 90 dB (A), that is, a threshold limit for commencement of hearing damage, exposure limits have downward values and thus, the rating is either high or very high (Table-1)

Table 1: Sources of Noise Generation and their Ratings at PHRC.

S/NO	NOISE SOURCE	AVERAGE * NOISE LEVEL, dB(A)	REMARKS ON NOISE LEVEL
1.	Air coolers/Fans	90.34	High
2.	Boilers	91.06	High
3.	Compressors	87.91	Moderate
4.	Condensers	94.10	High
5.	Heaters	90.36	High
6.	Gas Flare	64.89	low
7.	Pumps	88.50	Moderate
8.	Turbine Generators	90.85	High
9.	Stream Traps/Valves	94.60	High
10.	Reactors	92.10	High

* Average values were computed from measurements of some equipment type (noise source).

For Noise Level (NL) rating we have:
(i) Low for NL < 80 dB(A)
(ii) Moderate for NL between 81 & 90 dB(A)
(iii) High for NL between 91 & 100 dB(A)
(iv) Very High for NL > 100 dB (A)

In addition to noise level measurements for equipment (noise sources) spot readings were equally taken at office buildings, labs, control rooms, workshop, etc in order to access the level of noise staff have to contend with during working hours on a daily basis. Noise levels in-or-out-side the building varied from a minimum of 40.0 dB (A) at a Secretary's office to a maximum of 86.7 dB (A) at a machine room (main lab.)

3.2 Spatial noise level survey

The identification of the locations of noise sources aided in the judicial selection of routes form the study of spatial distribution and dispersion of noise pollution. The spatial variations of noise levels were measured at intervals of 30 meters along four selected route designation (A,B,C, and D) to cover the entire PHRC premises (Fig. 1). A total of 29 kilometers of distance and 94 point locations for spot readings were covered in the course of the measurements.

4. RESULTS AND DISCUSSION

4.1 Spatial variation of noise level

The measured noise levels in decibels are plotted against distance in metres for each of the four routes (Fig. 2), For the first plot, RA consider route designation - A (Fig. 1) which covers a total distance of 410 metres measured from the road crossing {taken as the Bench mark, BM (zero metre)} to the fence. At the bench marks, NL reads 68.5 dB (A) and increases to 82.5 dB(A), 60m away from BM

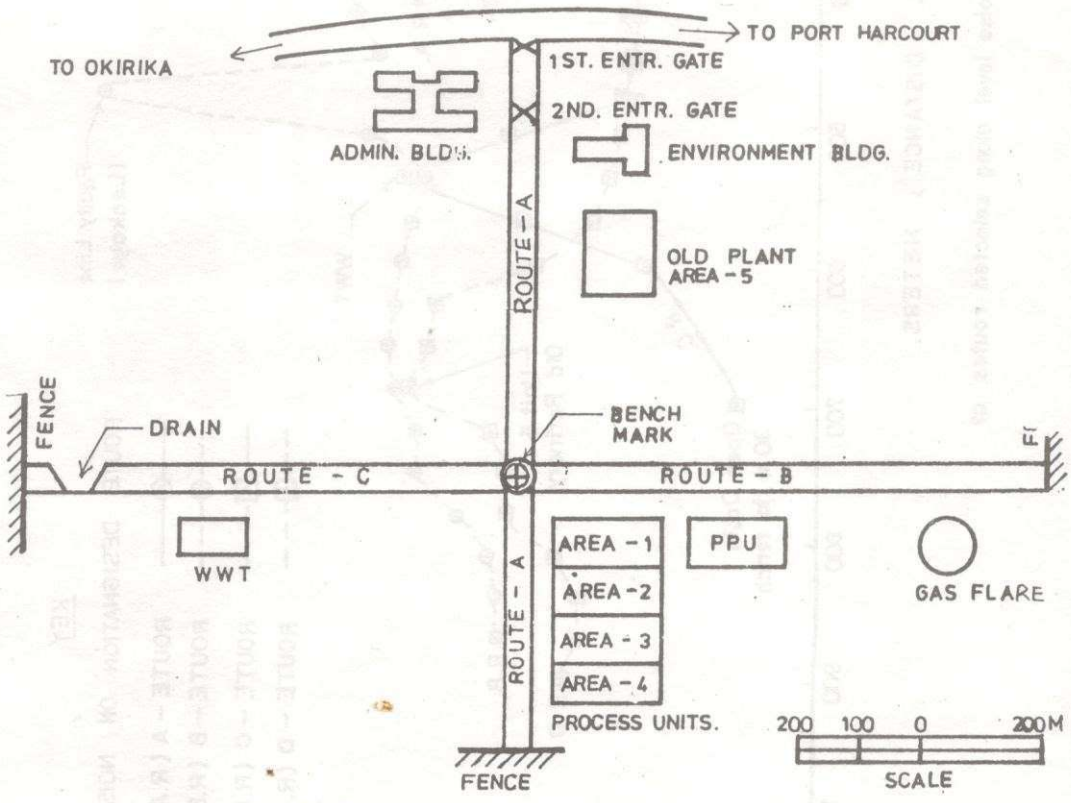


Fig 1. Route designation map for spacial noise level Distribution in porthacourt refinery premises

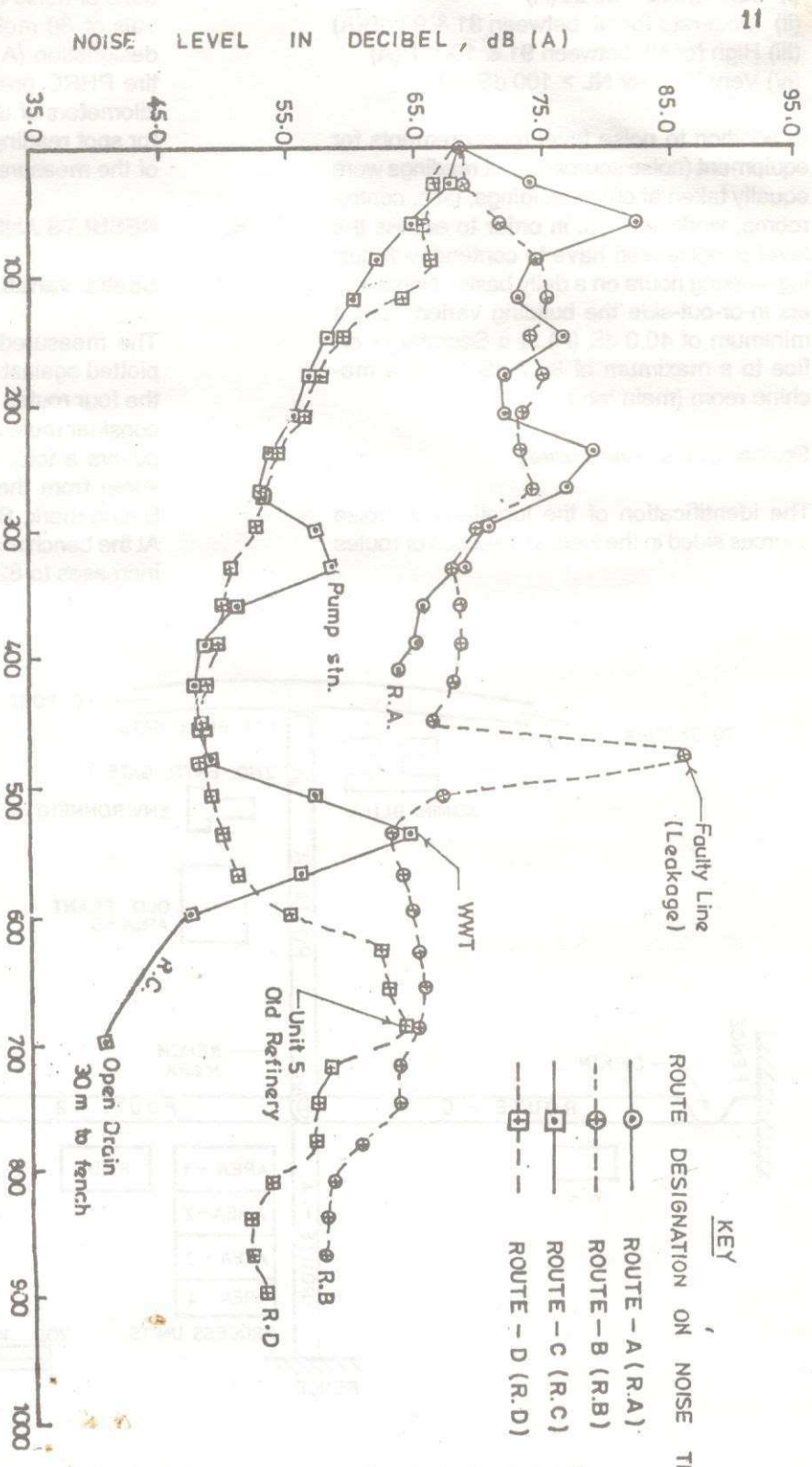


FIG. 2 Spatial distribution of measured noise level along selected routes at Port harcourt refinery premises.

due to the proximity of a noise source within the process unit. Along this route certain major noise sources are found which includes pumps, steam traps for the storage tanks, compressors, air tank etc of the process plants.

Beyond the 60m points, the NL falls to 73 dB(A) in additional 60m distance hereafter undergoes a rise to 76 dB (A), 30m away; a fall to 72dB (A), 60m away; another rise to 79dB(A), 30m away; and a consistent fall to 63.4dB(A), 180m away; all depicting a non-linear variation. As evident from the plot RA, as the noise level disperses away from source measurement, any sudden rise indicates proximity to a fresh noise source.

The second, third and fourth plots (RB, RC and RD) along routes - B,C and D cover individual distances of 870, 700, and 900 metres, respectively. Similar to plot RA, the plot RB exemplified non-linear variations; with rise and fall in NL with respect to distance along its route due to sparsely located noise sources. On the other hand, the plots RC and RD, though non-linear, exemplified the effect of one noise source (at BM) propagated some distance with less or no interference by additional noise sources. The trend in plot RC or RD is one of the peak in noise level at a source (BM) and a decay of some rate away from the source with minor interruption near the terminal point. In fact, the interference as per the noise decay rates along plots RC and RD are due to the proximity of Waste Water Treatment, WWR plant and the old Refinery at Area-5, respectively.

Additional observation from the four plots of Fig. 2, are noteworthy. The plots RA and RB are consistently lying above plots RC and RD. The reason is well explained above as "the effect of noise decay or dispersion due to one noise source with less or no interference in-between". Recall that the four (4) plots originated from a point, 68.5dB)A) and the dispersion of this value without additional noise source proximities as in the cases of plots RC and RD is bound to decrease reasonably below the initial value. And this is what has happened in plots RC and RD, respectively.

4.2 Estimates of rate of noise dispersion

The rate of noise dispersion may be taken herein as the amount of decay in decibels per unit distance in meter. Two average rates of noise level dispersion from Fig. 2, one for plots RA and RB as 0.052 dB(A) per metre; and another for plots RC and RD as 0.062 dB(A) per metre. Use can be made of these noise level dispersion rates along the applicable routes in the PHRC premises to estimate or model noise levels beyond the block fences or boundaries of the premises. However, caution must be exercised in the use of such dispersion rates, taking cognizance of any background (ambient) noise that should be superimposed on the dispersed noise in order to obtain reasonable forecast at points of interest. Also, decibels are logarithmic ratios of two pressures and as such noise levels emitted from two sources cannot be added arithmetically. The principle of superimposition (combined effect of compound noise) is somewhat complicated but simplified by use of charts (Vesiland & Peirce 1983). And this should be adopted in noise dispersion modelling.

The dispersed noise levels at the three fenced boundaries along routes - A, B, and C; and at the entrance gate, along route D are noted as 63.4, 57.0, 40.0 and 53.0 dB(A) respectively. In effect, noise levels generated within the PHRC premises are spatially well dispersed, and at the block fence (boundaries) noise levels are far below FEPA's recommended permissible limits. Thus, any noise emitted to the neighborhood may not constitute a health hazard.

4.3 The positive aspects of noise

One aspect of noise that is useful is its utility in quality monitoring of equipment performance. Noise generation through equipment use may be taken herein as a function of equipment model technology, age, hourly performance, etc. Older machines are subject to frequent breakdowns, reduced efficiency after long use over heating during high temperature condition and noisier. Likewise, a faulty equipment or machine develops in most cases a very unusual noise and our ability to exploit this phenomenon as a tool in quality monitoring of equipment and offers significant savings in maintenance.
The noise level field survey results of the PHRC can be employed to demonstrate the positive aspects of noise. For instance, when the plotted spot readings of noise sources as

in Figs 3 and 4 are contrasted with the average values of the same type of equipment (see Table-1), it is possible to isolate those with unusually high noise levels indicating poor performance. Consider the cases of air fans and pumps of which the total numbers are 133 and 103, and their corresponding average readings are 90.3 and 88.5 dB(A), respectively. For air fans a combine analysis of Fig. 3 and the method of grouping of data into class intervals (Table 2) indicate that 35.3, 26.6 and 42.1 percents are below within and above average value, respectively. Thus, three broad classifications of air fans' status conditions have emerged from the above data analysis.

The first class belongs to the below average value (zone - A, 14.3%), wherein the air fan condition is such that age and/or use affect performance minimally. The second and third classes belong to within and above average values (zones B and C, 77.4 and 8.3%) wherein age and/or use affect fans' performance reasonably, and adversely, respectively. For the third class a fault is likely to have developed.

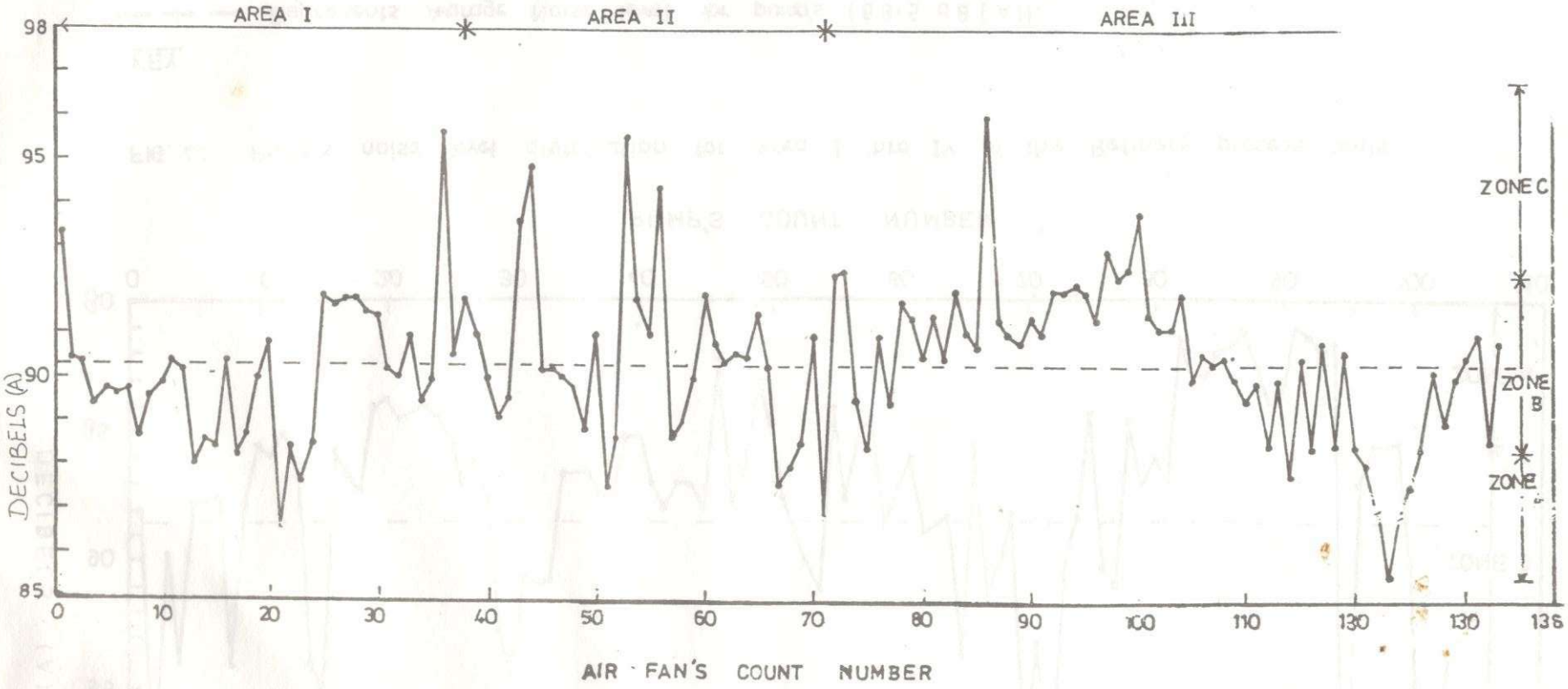


FIG. 3 : Air Fan's noise level distribution for Area I thro IV of the refinery process units.

KEY

— — — Represents average noise level for air fans (90.3 dB (A)).
Zones A thro C Represent status classification of air fan's conditions (see table 2).

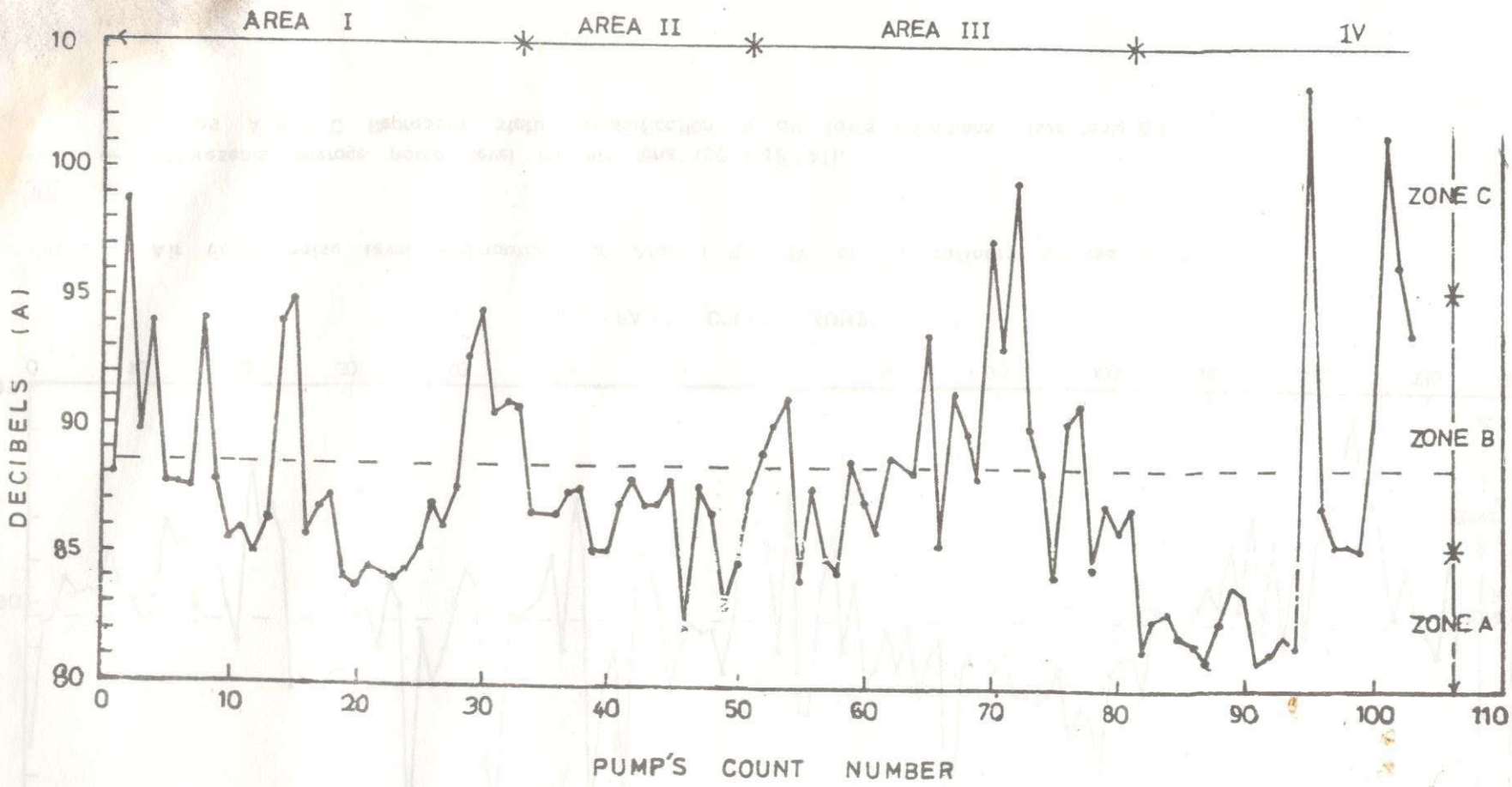


FIG. 4: Pump's noise level distribution for Area I thro IV of the Refinery process units.

KEY

— — — Represents Average Noise level for pump's (88·5 dB (A)).

Zones A thro C represent status classification of pump's conditions (see table 2)

Table 2: Air Fans Noise Level Classification

	NO OF AIR FANS			NOISE LEVEL CLASSIFICATIONS		
	BELOW AVERAGE	WITHIN AVERAGE	ABOVE AVERAGE	CLASS INTERVAL	NO. OF AIR FANS	ZONE*
I	17	10	11			
II	13	8	12	86.5 - 88.4	19	A
III	15	9	31	88.5 - 92.4	103	B
IV	2	3	2	92.5 - 96.4	11	C
	47 (35.3%)	30 (22.6%)	56 (42.1%)		133	

* Result indicates 3 broad classifications, namely:

Zone - A Age and/or use affect performance minimally;

Zone - B Age and/or affect performance reasonably; and

Zone - C Age and/or affect performance adversely and a fault is likely

Similar to air fans, pumps' noise level classifications are presented in Table 3 with details of the noise level distribution shown in Fig. 4, covering Areas - 1 thro IV of the Refinery Process Units. Results indicate that about 33.0, 62.1 and 4.9 percents belong to the three broad classifications of zones - A, B, and C, respectively. The pumps in zone B may be reviewed for routine servicing while those in zone C may require detailed maintenance analysis for faults.

5. CONCLUSION

The need for noise pollution studies in an industrial environment has been demonstrated using the Port Harcourt Refining Company. Two focal points in the study are the estimates of the rates of noise dispersion from sources to the surroundings; and some review of the positive aspects of noise in quality monitoring of operating equipment. Analysis of the field spatial and spot readings at 1.0m from noise sources reveal the following results:

(i) Of 10 noise producing equipment, 70% are rated as high (91 - 100 dB(A)), 20% as moderate (81 - 90 dB(A)), and 10% as low (below 80 dB(A));

(ii) Two average rates of noise dispersion are computed as 0.052 and 0.062 dB(A) per meter as representative of the entire study area (PHRC);

(iii) Noise levels generated within the PHRC premises are "spatially well dispersed" and at

the fenced boundaries noise levels are well below the FEPA's recommended permissible limit of 90 dB(A). Thus, any noise emitted to the neighborhood may not constitute a health hazard.

For the positive aspects of noise, analysis of data confirmed three broad classification of the 'status conditions' of equipment namely air fans and pump. The 1st, 2nd and 3rd classes belong to those wherein age and/or use affect performance minimally, reasonably or adversely, respectively. A fault is usually associated with the 2nd and 3rd classes.

Table 3: Pumps' Noise Level Classification

	NO OF AIR FANS			NOISE LEVEL CLASSIFICATIO		
	BELOW AVERAGE	WITHIN AVERAGE	ABOVE AVERAGE	CLASS INTERVAL	NO. OF AIR FANS	ZONE*
I	22	0	11	80.5 - 85.4	34	A
II	17	0	0	85.5 - 95.4	64	B
III	12	6	12	95.5 - 105.4	5	C
IV	18	0	5			
	69 (67.0%)	6 (5.8%)	28 (27.2%)		103	

* Result indicates 3 broad classifications, namely:

Zone - A Age and/or use affect performance minimally;

Zone - B Age and/or affect performance reasonably; and

Zone - C Age and/or affect performance adversely and a fault is likely

6. ACKNOWLEDGEMENT:

This study was supported by the Port Hacourt Refinery, PHRC. The authors wish to extend sincere thanks to the managements of PHRC for their support; and that of GAZEMS VENTURES that coordinated the project and the manuscript preparation.

7. REFERENCES:

1. Ezenwa, A. (1985) Community Health and Safety in the Tropics 1st ed.. Published by Safety Science Lagos, Nigeria

2. Federal Environmental Protection Agency, FEPA (1991); Guidelines and Standard for Environment Pollution Control in Nigeria, pp238

3. Gazems Ventures (1993a); "Noise Pollution Abatement study of Obagi Flowstation, Consultancy Report No. 01/93, submitted to ELF Petroleum (Nig) Limited, in February.

4. Gazems Ventures (1993b): Noise Pollution Abatement study of Port Harcourt Refining Company, PHRC" Consultancy Report N. 02/93, submitted to Port Harcourt refining Company Limited in October.

5. Kuronem, J. (1988): " Noise Control in Woodworking Industry" Woodworking Industries Safety, Kolka, Finland, pp 183 - 193.

6. Nwagazie, I.L. (1990): " Pollution Modelling: A necessity for provision of water for all in Nigeria", Nig. Jour. Technological Research, vol. 2, pp 49 - 55.

7. Vesilind, P.A and J.j Perice (1983: Environmental Pollution & Control, 2nd ed., Published by Ann Arbor Science, Butterworth Ltd., England.