NOISE RADIATION EVALUATION FROM GAS FLARING BY MATHEMATICAL SIMULATION. A CASE STUDY OF THE NIGER-DELTA AREA.

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A PROJECT SUBMITTED TO THE DEPARTMENT OF CHEMICAL ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR DEGREE IN ENGINEERING.

NOVEMBER, 2004.

DECLARATION

I ABOLOYE .O. OLADIPO B.ENG/CHEM/98/7101EH,hereby declare that this thesis: NOISE RADIATION EVALUATION FROM GAS FLARING BY MATHEMATICAL SIMULATION. A CASE STUDY OF THE NIGER-DELTA AREA, presented for the award of bachelor in chemical engineering, has not been presented for any other degree any where else.

....	24/11/04 ....
SIGNATURE	DATE

CERTIFICATION

This is to certify that this project was supervised, moderated and approved by the following under listed persons on behalf of the chemical engineering department, school of engineering and engineering technology, federal university of technology Minna.

.... 17/11/2004

ENGINEER ABDULKAREEM S.A DATE

(PROJECT SUPERVISOR)

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(HEAD OF DEPARTMENT)

....

XTERNAL SUPERVISOR DATE

DEDICATION

I dedicate this project to the almighty God for his abundant blessings and favors and also to my family and friends, my anchor in this hectic life.

ACKNOWLEDGMENT

I wish to express my profound gratitude to my supervisor Engr. S.A Abdulkareem for his guidance, fatherly advice and assistance in ensuring the successful completion of this project work. My appreciation also goes to the head of department, Dr F.A Aberuagba and the entire staff of the chemical engineering department (teaching and non-teaching).

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ABSTRACT

The flaring of natural gas during the exploration and exploitation of crude oil in the Niger-Delta area of Nigeria has brought about pollutants of all kind. One of the major pollutants is the noise radiation emanating from these gas flaring stations. Noise radiation produces many adverse effects on man and other animals. Analysis of experimental results of noise radiation dispersion from flare station was explored using VBASIC program. It was observed that the model and experimental values to a large extent conform to the conceptualized pollutant migration pattern. Simulation results of the developed model show that the noise intensity level reduces with increasing distance from the flare point and that weather is an important influence on noise radiation propagation. Inhabitants of the Niger-Delta area should therefore situate their homes and perform their activities outside the determined unsafe zone of flaring.

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CHAPTER ONE

1.1 INTRODUCTION

Nigeria is richly blessed with abundant natural resources such as crude petroleum and natural gas. The exploitation of these energy resources leads to unnecessary wastage of natural gas by flaring. Due to unsustainable exploitation practices coupled with the lack of gas infrastructure in Nigeria. The country flares 75% of the gas it produces and re-injects only 12% to enhance oil recovery (Charles, 2003).

It is estimated that about 2 billion cubic feet of gas is currently being flared in Nigeria, the highest in any member nation of OPEC (Charles, 2003), and the majority of the oil exploration activities take place in the Niger-Delta area of Nigeria because this region accounts for 75% of Nigeria's petroleum resources (Charles, 2003).

The multitude of flaring activities in the Niger-Delta region of Nigeria have enormous adverse effects on both the environment and its inhabitants, these include the of green house gases, smoke, soot and. The noise emanates from flaring of natural gases at elevated temperatures thereby constituting a local problem in the immediate surroundings of the flare stations (Oyekunle, 1999). Noise is a class of sound that is considered as unwanted in some situations. Noise may adversely affect the health and well being of individuals and population. It has been agreed by experts that it is not possible to define noise exclusively on the basis of physical parameters of sound, instead it is common practice to define noise operationally as audible acoustic energy that affects, or may affect the physiological and psychological wellbeing of people (WHO, 1995).extremely intense continuous or impulsive noise can cause hearing loss, hearing impairment, increase in blood pressure and increase in anti-social behaviour (Connell, 1972).

However, efforts are being made to control the effect of the resultant noise pollution in the Niger-Delta area by the federal government by promulgating decrees which will mitigate gas flaring to its barest minimum. But Nigeria dependence on the exploitation of crude petroleum has hampered the implementation of these decrees and also the oil companies involved will not want to end gas flaring in their own interest because of the financial investment in terms of technology applications to be used to achieve this. Consequently, flaring of associated gas has continued and the people of Niger-Delta are still exposed to serious environmental deterioration.

It is on this basis that a mathematical model which is a tool of control shall be developed for noise radiation evaluation from gas flaring station in the Niger-Delta area. The mathematical model developed shall be used in predicting the effect of noise on the immediate environment.

Modelling is a method of study which the object of process of interest is replaced with its model on which necessary tests are carried out and the result are extended to the prototype (Abdulkarem, 2000). A model which is the replica of the actual plant or process may be in form for a set of mathematical equation, chart, table etc. mathematical modelling of a system gives the description of the process where both physical and chemical phenomenon takes place therein. It therefore aims at providing the simplest possible description of the system if which it is an exact, or scaled down replica of the prototype and retains its physical character (William, 1995).

Simulation represents the application of modelling techniques to real system, thus enabling information on plant characteristics to be gained without either constructing or operating the full scale plant or system under consideration (Abdulkarem, 2000).

1.2 AIMS AND OBEJCTIVES

The aim of this project is to develop a predictive model for noise radiative evaluation from gas flaring station in the Niger-Delta area. This can be achieved trough the following ojectives:

1. Determine the noise radiation from gas station using the model.
2. Collation of data and experimental analysis from gas flaring station to confirm the validity if the model.
3. Develop a computer package for the model and simulate the developed computer programme using visual basic to find interrelation between various parameters such as distance, volume of flare, wind speed, temperature etc.

1.3 SCOPE OF WORK

This work is aimed at developing a method of predicting the effect of noise radiated from gas flaring on the immediate environment in the Niger-Delta area by the application of computer simulation. This work is limited to experimental results obtained from four flare stations covered within the period of twelve months.

1.4 JUSTFICATION

The Nigerian economy is over-dependent of the sale of petroleum and this is directly connected to the exploitation and exploration of crude petroleum. During this process, the inability and utilise the associated natural gas leads to the flaring if these gases. This development has led to massive pollution (both noise and otherwise) of the oil producing areas in Nigeria especially in the Niger-Delta and this has some adverse effect in the inhabitants of such areas.

However, series of research have been carried out on the effects of gas flaring in the Niger-Delta area. (Oyekunle 1999) investigated the effects of gas flaring on environment and pollution control. Odigure and Abdulkarem (2000) carried out evaluation on heat radiation from gas flaring by computer simulation. Abdulkarem (2000) developed a mathematical modelling for pollutant migration from gas flaring.

Although it can be observed that substantial work has been done on gas flaring, but little has been done so far on the modelling and simulation of noise radiative evaluation from the gas flaring point, this project seeks to develop a mathematical method of predicting the effect of radiative noise emanating from gas flaring on the immediate environment.

CHAPTER TWO

2.0 LITERATURE REVIEW

Nigeria is a country so blessed with natural gas that it ranks 9th in the world and 2nd in Africa in its reserves (Charles, 2003). Nigeria has an estimated 180 billion cubic feet of proven natural gas, but due to unsustainable exploration in Nigeria, the country fares 75% of the gas it produces (Charles 2003) and re-injects only 12% to enhance oil recovery (Charles 2003). It is estimated that about 2 billion cubic feet of gas is currently being flared in Nigeria, the highest in any member nation of OPEC (Charles 2003). This is an enormous flare amount which accounts for about 19% of the total amount of gas flared globally, one may wish to point out that the Niger-Delta region in Nigeria makes up 80% of the region where these flaring occurs and also accounts for 75% of Nigeria's petroleum resources (Charles 2003).

Gas flaring in the Niger-Delta is a major cause of environmental pollution in the region and also major cause damage to human health. A world bank study "defining an environmental development strategy for the Niger -Delta" (1995), estimates that as much as 75% of all natural gas from petroleum production in Nigeria in flared compared to 0.6% in USA ,and 4.3% in the UK. In another study, as shown in the table 2.0 that Nigeria contributes the highest quantity of gas flared when compared with some of the major oil producing countries in the world (Daily times, 1998).

The flared of gas is a very serious hazard, the multitude of flares in the Niger-Delta burning at temperatures ranging from 1300^{0}C to 1400^{0}C heat up the environment. Gas flaring so cause noise pollution and produces a lot of gaseous pollutants like CO2, CO, NO2 and particulate around the clock. The emission of CO2 from gas flaring in Nigeria releases 35million tons of CO2 a year and 12 million tons of CH4, which means that Nigerian oil fields contribute more in global warming than the rest of the world put together (TELL, 1996).

Taking into consideration the serious deterioration of the basic characteristics of the environment as a result if harmful pollutants released into the atmosphere, it has become necessary to seriously consider environmental management as a priority project if improved quality if life for all living being is to be guaranteed. In view of this, the federal environmental protection agency (FEPA) was set up by the Nigerian government with the sole objective of reducing environmental pollution of any type from process industries. The body is far from achieving its goal for which it was formed.

Table 2.1 showing the amount of gas flared by some oil producing nations

COUNTRY	GROSS PRODUCTION	FLARED	% FLARED
ALGERIA	97,400	7800	8.0
ECUADOR	740	630	85.1
Gabon	1,994	1,369	68.6
Indonesia	46,300	3,080	6.6
Iran	33,000	4,950	15.0
Iraq	8,270	6,620	80.0
Kuwait	6,670	670	10.0
Libya	12,900	700	5.4
Nigeria	18,739	13,917	74.2
Qatar	6,150	-	-
Saudi Arabia	40,500	2,800	6.9
United Arab emirate	23,520	4,950	21.0
Venezuela	36,275	2,775	7.6
TOTAL	332,458	50,261	15.1

An analysis of the table 2.1 data shows that in terms of the share of the total quantity if gas flared, Nigeria contributed the highest quantity; with approximately 27.7% while Qatar had 0%.

The practice of gas flaring is not only wasteful in terms of resources but also extremely harmful to the human health and environment. Human health has suffered so much that the Niger-Delta is now a place where life is short and unpredictable, where so much wealth is extracted and where so much wretchedness is evident (Abiodun Raufu, 2002). The extent of human damage attributed to gas flaring is unclear, but doctors have found an unusually high incidence of asthma, bronchitis, skin and breathing problems in communities in oil producing areas (Obadina, 2000). In addition to the lung disease related to gas flaring, the pumping of mud waste into marine environments may be responsible for food borne poisoning and illness. Other side effects are noted in diminished food supplies, increased cases of hypertension and endocrine imbalance (Abiodun Raufu,2002)

The negative effects of gas flaring do not stop on human health and environment alone, but is also affects the growth of plants. Research by ecologist suggested that routine flaring of gas at Niger-Delta facilities has stunted plant growth and reduced crop yields in the region (Peace Magazine, 1998). Some of the flaring stations are only a few meters from human dwellings. Consequently, inhabitants of the Niger-Delta area are exposed to perpetual heat, high noise level and constant daylight conditions with the physiological and psychological disorder that goes with them. The constant daylight condition, in which even night looks like day, interferes with the human circadian rhythm (Abiodun Rafau, 2002)

A critical work on the adverse effects of noise emanating form gas flaring stations has not been carried out extensively. Thus, this necessitates the use of a model which is a tool of control to help in evaluating the extent of noise pollution in the Niger-Delta area. The use of modelling could eliminate the time and material wastage in carrying out experimental work.

2.1 MATHEMATICAL MODELLING AND SIMULATION

A model is a simplified representation of a system intended to enhance our ability to understand, explain, change, preserve, predict and possibly control the behaviour of a system (Abdulkareem, 2000). Models of various kinds are used extensively to provide representations of some aspect of the real-world system of interest (William, 1995).

In recent years, engineering firms have made extensive use of models as guides to efficient construction. Such models are especially practical for projects involving the construction of processing plants for the petroleum and chemical industries, where intricate piping is required to carry liquid and gases. Models are developed for many reasons; to enable the investigation of a given systems behaviour, to enable a scenario to be considered to provide a more convenient medium of discussion of certain features (William, 1995). Modelling is thus, the process of establishing interrelationship between important entities of a system (Abdulkarem, 2000). Simulation is a technique for conducting experiment on a model using computer so that the experiment is possible without any risk while the results are very illustrative (Abdulkarem, 2000). It is also a technique of constructing and running model of a real system in order to study its behaviour without disrupting the environment of the system.

A mathematical model is itself a discipline for it enables relationships between defined quantities to be expressed in terms of representative mathematical symbols and statements. Mathematical model thus aims at providing the simplest possible description of the system, which is an exact, or scale down replica of the prototype and retain its physical characters (Encyclopaedia of science and technology, 1978).

Simulation represents the application of modelling techniques to real systems, thus enabling information on plant characteristics to be gained without either constructing or operating the full scale plant or system under consideration (Abdulkarem, 2000).

Modelling and simulation are inseparable procedures. They include activities associated with the construction of a model representing real processes and experimentation with the models to obtain data on the behaviour of the system being modelled.

Modelling can be used as a tool of control in evaluating noise radiation from flaring stations in the Niger-Delta. Noise is one of the many environmental pollutants caused by gas flaring in the Niger-Delta.

2.2 NOISE POLLUTION

Noise pollution is the excessive noise or unwanted sound contributed to the environment by human activities. Noise is considered a pollutant when it is present in sufficient quantity and intensity to cause psychological damage to people in the environment (McGraw-Hill Encyclopaedia, 1982)

Noise is defined operationally as audible acoustic energy that adversely affects or may affect the physiological and psychological well being of people (Connell, 1972). The world and its cities are steadily growing nosier. Public health doctors and specialists in hearing disorder use the term noise pollution to describe the menace of prolonged unwanted and unpleasant sound (Connell, 1972)

For centuries noise has been a nuisance. Scientists and physicians have gathered evidence showing the effect of excessive noise. Besides a temporary or permanent loss in hearing ability; constant exposure to loud noise can cause nervousness and fatigues (Connell, 1972). Some doctors think it may also be responsible for a variety of illness. But apart from its effect on hearing, noise distorts sounds that people want to hear, hinder concentration and interfere with sleep and rest.

2.2.1 SOURCE OF NOISE

Like other pollutants, noise is often concentrated where population and activities are concentrated. The problem of noise pollution is acute in city streets where heavy traffic is a major source of noise, building and construction sites. In industrial cities, factories can be further sources of noise. Mechanised industry creates serious noise problems, subjecting a significant fraction of the working population to potentially harmful sound pressure levels (sound intensity) i.e. noise. In industrialised countries, it has been estimated that 15-20% or more of the working population is affected by sound pressure levels of 75dBA-85dBA (Berglund and Lindvall, 1995). This noise is due to machinery all kinds and often increases with the power of the machines. The characteristics of industrial noise vary considerably, depending on specific equipment. Rotating and reciprocating machines generate sound that is dominated by total and harmonic components; air-moving equipment tends to generate sounds with a wide frequency range. The highest sound pressure levels are usually caused by component, or gas flow that moves at high speed (e.g. fans, steam pressure, relief-valves) or by operations involving mechanical impacts (e.g. stamping, riveting, and road breaking).

In residential areas, noise may also emanate from mechanical devices (e.g. Heat pumps and ventilation systems, traffic, also within the home electrical appliances are all capable of causing undesirable noise. Due to low frequency characteristics, noise form ventilation system in residential building may cause considerable concern even at low and moderate sound pressure level (Berglund and Lindvall; 1995).

Other sources of noise are transportation noise i.e. road traffic, rail traffic, sonic booms (shock wave system in air generated by aircraft when it flies at a speed slightly greater than the speed of sound), construction noise, public noise and military noise.

2.2.2 DEFINITION OF SOUND AND NOISE

Physically sound is produced by mechanical disturbance propagated as a wave motion in air or other media. Physical sounds evoke physiological responses in the ear and auditory pathway (Berglund and Lindvall, 1995). These responses can be described and measured using appropriate methods with, for example, physical parameters (like vibratory motion of the ear drum membrane) or with electro-physical parameters (changes in bioelectric potential in the sensory and neural tissues). However, not all sound waves evoke auditory-physiological response, for example, ultrasound has a frequency too high to excite the auditory system and, thus, to evoke sound perception. Audible sounds are produced when an object vibrates, causing the air molecules next to its surface to be alternately pushed together and pulled apart. The air is first compressed, and then rarefied. As these air molecules move back and forth, they collide with neighbouring molecules. A series of compression and rarefactions is thus transmitted. If these transmitted vibration occurs within a certain frequency range (the audible range), the alternating vibrations of the ear adjacent to the eardrum cause it to vibrate in sympathy. These vibrations are then transmitted through the ear to the brain, where they are interpreted as sounds. From a physical point of view there is no difference between the concepts of sound and noise, although it is an important distinction for the human listener. Noise is defined operationally as audible acoustic energy that adversely affects, or may affect the physiological and psychological well being of the people (Berglund and Lindvall, 1995) a class of sounds that are considered as unwanted. In some situations, but not always, noise may adversely affect the health and well being of individuals or populations.

2.2.3 EFFECT OF NOISE ON MAN

Noise is a stress, and as such produces many varied effects on man and other animals. In heavy industries, neuro-sensory hearing loss among employees occurs frequently and is irreversible.

In addition, many studied have indicated that continued exposure to loud noise through its effect on the nervous system can exposure to loud noise through its effect on the nervous system can produce harmful effects on many systems. Some investigators have also pointed to a casual role of noise in such diverse ailments as pointed to a casual role of noise in such diverse ailments as ulcers and hives (Rosen, 1978). Loud noise also influences man's physiological well being, and investigations on both animal and human subjects have revealed that noise can affect foetuses, causing them to stir in the uterus and perhaps be overactive, cry easily, and be subject to gastrointestinal upset after birth (Rosen, 1978).

It is widely believed that people become accustomed to noise and that therefore it does not harm them. However, unlike the eyes, which can be closed against strong light, the ears are always open and vulnerable. Loud noises cause effects that the recipient cannot control and to which his/her body never gets accustomed. The blood vessels constrict, the skin pales, the muscles tense, and one of the adrenal hormones-ACTH-is suddenly released into the blood stream increasing the physical signs of tension and nervousness (Rosen, 1978).

Other investigators have shown that even mild sensory and mental annoyance resulting from pollution can provoke significant elevations in cortisol (an adrenal hormone) levels in plasma. This in turn increases the heart rate of blood pressure, especially in emotionally excitable persons.

In an animal experiment, rabbits exposed to 102dB of noise for 10 weeks showed a much higher level of blood cholesterol than did similarly fed rabbits not exposed to noise (Rosen, 1978). The noise exposed animals developed a greater degree of aortic arteriosclerosis with higher cholesterol deposit in the iris of the eye (Rosen, 1978). Several investigations have demonstrated in animals tissue studies that noise cause's vasoconstriction of the cochlear vessel n the ear, accompanied by a significant reduction in the flow of blood and number of red blood lls reaching the internal organs of the ear. The vasoconstriction of the cochlear vessels probably causes anaemia, and the sensory cells show structural changes leading to loss of function (Rosen, 1978).

2.3.1 INTERFERENCE WITH COMMUNICATION

Noise tends to interfere with auditory communication, in which speech is a most important signal. The effect of exposure to high levels of noise can be very damaging psychologically causing interference with speech resulting in a great proportion of person disabilities and handicaps such as problems with concentration, fatigue, uncertainty and lack of self confidence, irritation, misunderstandings problems in human relations (Berglund and Lindvall, 1995).

However, it is also vital to be able to hear alarming and informative signals such as door bells, telephone signals, alarm clocks, fire alarm etc; as well as sounds and signals involved in occupational tasks. For communication distance beyond a few meters, speech interference starts at sound pressure levels below 50dB for octave bands centred on the main speech frequencies at 500, 1000, and 2000Hz (WHO 1999).

A majority of the population belongs to groups sensitive to interference with speech perception. Most sensitive are the elderly and persons with impaired hearing. Even slight hearing impairments in the high-frequency range may cause problems with speech perception in a noisy environment. From about 40 years of age, people demonstrate impaired ability to interpret difficult, spoken message with low linguistic redundancy, when compared to people aged 20-30 years (WHO, 1999). It has also been shown that children, before language acquisition has been completed, have more adverse effects than young adults to high noise levels and long reverberation times.

2.3.2 SLEEP DISTURBANCE EFFECTS

Electro physical and behavioural methods have demonstrated that both continuous ad intermittent noise indoor s lead to sleep disturbance. The more intense the background noise, the more disturbing is its effect on sleep. Measurable effects on sleep starts at background noise levels of about 30dB (W.H.O, 1999). Physiological effects include changes in the pattern of sleep stages. Subjective effects have also been identified, such as difficult in falling asleep, perceived sleep quality and adverse after effects such as headache and tiredness. Sensitive group mainly include elderly persons, shift workers and persons with physical or mental disorders.

Where noise is continuous, the equivalent sound pressure level should not exceed 30db indoors, if negative effects on sleep are to be avoided (WHO, 1999). When the noise is composed of a large proportion of low-frequency sounds a still lower guideline value is recommended, because low frequency noise (e.g. from ventilation systems) can disturb rest and sleep even at low sound pressure levels. It should be noted that the adverse effects of noise partly depends on the nature of the source. A special situation is for newborns in incubators, for which the noise can cause sleep disturbance and other health effects.

2.3.3 EFFECTS ON PERFORMANCE

The effects of noise on task performance have mainly been studied in the laboratory and to some extent in work situations. But there have been few, if any, detailed studies on the effects of noise on human productivity in community situations. It is evident that when a task involves auditory signals of any kind, noises at intensity sufficient to mask or interfere with the perception of those signals will also interfere with the performance of the task. A novel event, such as the start of an unfamiliar noise, will also cause distraction and interfere with many kinds of tasks. For example, impulsive noise such as sonic booms can produce disruptive effects as the result of startle responses; and these types of responses are more resistant to habituation.

Mental activities involving high load in working memory, such as sustained attention to multiple cues or complex analysis, are all directly sensitive to noise and performance suffers as a result. Some accidents may also be indicators of noise related effects on performance, noise also has consistent after-effects on cognitive performance, with task such as proof reading, and on persistence with challenging puzzles. Chronic exposure to aircraft noise during early childhood appears to damage reading acquisition (W.H.O, 1999). Evidence indicates that the onger the exposure, the greater the damage.

4 HOW NOISE CAUSES HEARING LOSS

Noise induced hearing loss is of a sensory neural type involving injury to the inner ear canal and cause the eardrum to vibrate. The vibrations are then transmitted by the bones of the middle ear to the sensory organs, where they are perceived as sound (e.g. Noise). The inner ear is filled with fluid and has many tiny hairs that sound waves caused to vibrate. Each hair is connected to a hair cell, which when excited, send a message to the brain. The brain translated the signal into the sensation of sound. The loudness or softness of the sound that we hear depends upon the amplitude with which the vibrations reach our ears.

The hair cells react to the vibrations of a range of sounds. The louder the sound, the more hair cells are moved. The longer a loud sound (i.e. noise) goes on, the more likely the hair cells will become worn out and no longer be able to carry messages to the brain. Then hearing loss can occur. A person may not realize there is a hearing loss. It may just sound as if people are not speaking clearly.

2.4 RATING OF NOISE

Noise can be measured by means of a device called a sound level meter, which very roughly imitates the functioning of the ear. The meter detects sounds when the diaphragm of its microphone is vibrated by incoming sound waves just as the eardrum is vibrated when the ear is exposed to sound waves. Because sound travels as waves that are actually the temporary compressed and rarefaction of particles of air or any other elastic medium in its path, it causes a fluctuation in the pressure of the air adjacent to the diaphragm. This causes the vibration of the diaphragm which is converted to variations in an electrical current in the meter. The variations are in turn converted to a sound pressure level reading on the meter expressed in units called decibels (dB). The threshold of human hearing is near 0dB, which is equivalent to a sound pressure level of 0.002 dynes per square centimetre. The threshold of discomfort if approximately 120dB and that of pain is 130dB (W.H.O, 1999). Exposure to noise from various sources is most commonly expressed as the average sound pressure level over a specific time eriod; such as 24 hours. This means that identical average sound levels for a given time period ld be derived from either a large number of sound events with relatively low, almost dible levels, or from a few events with high sound level high sound levels.

WHO GUIDELINE VALUES

In view of the adverse psychological and physiological effect loud noise could cause to humans, the World Health Organisation published some guidelines values for community noise.

The W.H.O guideline values in table 2.2 are organized according to specific environments. When multiple adverse health effects are identified for a given environment, the guideline values are set at the level of the lowest adverse health effect (the critical health effect). An adverse health effect of noise refers to any temporary or long-term deterioration in physical, psychological or social functioning that is associated with noise exposure. The guideline values represent the sound pressure levels that affect the most exposed receiver in the listed environment.

The available knowledge of the adverse effects of noise on health is sufficient to propose guideline values for community noise for the following: (W.H.O., 1999)

(a) Annoyance

(b) Speech Intelligibility and communication interference

(c) Disturbance of information extraction

(d) Sleep disturbance

(e) Hearing impairment

The different critical health effects are relevant to specific environments, and guideline values for community noise are proposed for each environment. These are:

(a) Dwellings, including bedrooms and outdoor living areas.

(b) Schools and preschools, including rooms for sleeping and outdoor playgrounds

(c) Hospitals, including ward and treatment rooms.

(d) Industrial, commercial shopping and traffic areas, including public addresses, indoors and outdoors.

(e) Ceremonies, festivals and entertainment events, indoors and outdoors.

(f) Music and other sounds through headphones.

(g) Impulse sounds from toys, fireworks and firearms.

(h) Outdoors in parkland and conservation areas.

Table 2.2: Guideline values for community noise in specific environments.

Specific environment	**Critical health effect(s)**	**L_{Aeq} [dB(A)]**	**Time base [hours]**	**L_{Amax} fast [dB]**
Outdoor living area	Serious annoyance, daytime and evening	55	16	-
	Moderate annoyance, daytime and evening	50	16	-
Dwelling, indoors	Speech intelligibility and moderate annoyance, daytime and evening	35	16	-
Inside bedrooms	Sleep disturbance, night-time	30	8	45
Outside bedrooms	Sleep disturbance, window open(outdoor values)	45	8	60
School classrooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	During class	-
Pre- school, bedrooms, indoors	Sleep disturbance	30	Sleeping-time	45
School, playground outdoor	Annoyance (external source)	55	During play	-
Hospital, ward rooms, indoors	Sleep disturbance, night time	30	8	40
	Sleep disturbance, daytime and evenings	30	16	-
Hospitals, treatment	Interference with rest and recovery	#1		

rooms, indoors				
Industrial, commercial Shopping and traffic areas, indoors and outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/ year)	100	4	110
Public addresses, indoors and outdoors	Hearing impairment	85	1	110
Music through headphones/ earphones	Hearing impairment (free-field value)	85 #4	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -	- -	140 #2 120 #2
Outdoors in parkland and conservation areas	Disruption of tranquillity	# 3		

#1: as low as possible;

#2: peak sound pressure (not LAmax, fast), measured 100mm from the ear;

#3: existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low;

#4: under headphones, adapted to free-field values.

CHAPTER THREE

3.1 MATHEMATICAL MODELING OF NOISE RADIATION BY MACHINE IN FLARE STATION

In the exploration of crude petroleum and natural gas in the Niger-Delta region of Nigeria, a great amount of these resources are wasted and this can be attributed to flaring.

Flaring of natural gas has been an integral part of operation, at gas plant and flow station, associated with the exploitation of crude oil and natural gas in the Niger-Delta area. The multitude of flaring activities in the region has enormous adverse effects on both the environment and its inhabitants, these include the emission if greenhouse gases, smoke, soot and noise. The noise emanates from flaring of natural gas, thereby constituting a local problem in the immediate surroundings of the flare stations. This project is centred on noise radiation and propagation.

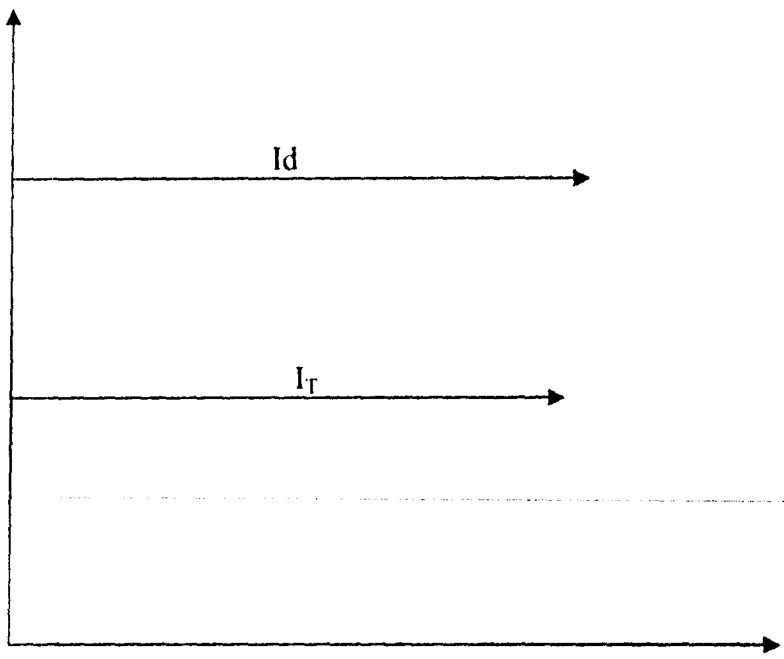
3.2 ASSUMPTIONS

The following assumptions were made in developing the mathematical equation for noise radiation from gas flaring.

1. Sound source is considered as a line source i.e. sound is radiated in a cylindrical manner.
2. The intensity at a point is equal to the sum of direct intensity and reverberation intensity.
3. Reverberant field on diffusion has a sound energy density E that is constant.
4. At steady state condition, power input to the reverberant field is equal to the rate of energy extracted from it.
5. Inverse square law is obeyed.
6. The initial wind blowing with a velocity W in the direction of sound propagation and the direction of wind velocity perpendicular tot ch discharge.
7. The effect of gravitational force will be neglected. So that constant equilibrium density of the air and constant equilibrium pressure in the air has uniform value through out
8. The air is homogenous, isotropic and perfectly elastic.

The schematic representation of noise intensity is shown in the figure 3.0 below;

Sound power, (P)



Distance d (m)

3.3 CONCEPTUALIZATION OF MODELLING TECHNIQUES

Reverberant Field

Consider sound power, p (watts) from a source. The sound remaining after one reflection is (Holmes et al, 1993)

$p - p\alpha$- ----------------------(3.1)

$p(1-\alpha)$ ----------------------(3.2)

Equation 3.2 is the sound power input to the reverberant filed.

α = absorption coefficient of the surface

total energy in space = nEV ----------------------(3.3)

Where

E = sound energy density (Nm^2)

n = number of reflection

v = volume (m^3)

Energy absorbed per reflection is:

$EC\ \alpha S$ -------------------------(3.4)

Where C = acoustic velocity (m/s)

S= surface area (m^2)

Under steady condition:

Power input to the reverberant filed equals to the rate of energy extracted from it

$P\ (1-\alpha) = EC\alpha S$ -------------------(3.5)

$$E = \frac{\mathrm{Pr}^2}{4Pc^2}$$ (Odigure et al, 2002) -------------------(3.6)

Where

Pr = root square of sound pressure in reverberant field which implies

$$P(1-\alpha) = \frac{\mathrm{Pr}^2\ \alpha CS}{4\rho c^2} = \frac{\mathrm{Pr}^2\ \alpha S}{4\rho c}$$ ------------------(3.7)

But $Ir = \frac{pr^2}{\rho c}$ = intensity in reverberant field (Blake, 1972)

Therefore:

$$p(1-\alpha) = \frac{Ir\alpha S}{4}$$ ------------------(3.9)

Thus, expression for the intensity in reverberant field is:

$$Ir = \frac{4p(1-\alpha)}{S\alpha}$$ -------------------(3.9)

Direct Field

Consider a noise of p (watts) in a place at a point d distance.

The intensity id is (Blake, 1972)

$$Id = \frac{QP}{\Pi d^2}$$ --------------(3.10) .

Where Q = direction depending on the situation of the source

Total intensity (I)

$$I = Ir + Id \qquad \text{---------------(3.11)}$$

$$I = \frac{4P(1-\alpha)}{S\alpha} + \frac{QP}{\Pi d^2} \qquad \text{--------------(3.12)}$$

But

$$S = \frac{\Pi d^2}{4} \qquad \text{--------------(3.13)}$$

Then,

$$I = \frac{16P(1-\alpha)}{\Pi d^2\alpha} + \frac{QP}{\Pi d^2} \qquad \text{--------------(3.14)}$$

Noise intensity level is;

$$L_I = 10\log\left(\frac{I}{I_{ref}}\right) \qquad \text{--------------(3.15)} \quad \text{(Blake, 1972)}$$

Where I_{ref} = References Intensity = $10^{-9}\ KW/m^2$

$$L_i = 10\log\left[\frac{16P(1-\alpha) + QP\alpha}{I_{ref}\Pi d^2\alpha}\right] \qquad \text{--------------------(3.16)}$$

From assumption 5, inverse square law is obeyed. This is because for a uniformly diverging wave (with no local reflecting surfaces or sources) , the intensity is inversely proportional to the square of the distance from the source.

Therefore;

$$L_i = 10\log\left[\frac{16P(1-\alpha) + QP\alpha}{I_{ref}\Pi d^2\alpha}\right] - \log\left[\frac{dT}{d}\right]^2 \qquad \text{---------------------(3.17)}$$

Where dT = total distance

But,

$$\alpha = \left(\frac{r-1}{r}\right)\frac{q}{zu} \qquad \text{-------------------------(3.18)}$$

Where

r = ratio of specific heat

u= velocity of sound in air

q = rate of cooling at constant volume of gas

$$\text{but } u = \sqrt{\frac{rp}{\rho}} \qquad \text{---------------------------(3.19)}$$

Where ρ = density of air

P = pressure

$$\text{And } P = \frac{RT}{V} \qquad \text{----------------------------(3.20)}$$

Where, R = Universal gas constant

T = temperature

V = volume of gas

Substituting (3.20) into (3.19) and making r the subject of formula:

$$r = \frac{u^2 v\rho}{RT} \qquad \text{-----------------------------(3.21)}$$

substituting (3.21) into (3.18)

$$\alpha = \frac{q}{zu}\left[1 - \frac{RT}{U\ v\rho}\right] \qquad \text{------------------------------(3.22)}$$

(WWW.engineeringtoolbox.com) stated that sound is propagated faster in a medium of high humidity

$$H_{sp} = 0.622Hz * \frac{\rho_{ws}}{(\rho - \rho_{ws})} \qquad \text{----------(3.23) (www.engineeringtoolbox.com)}$$

Where,

H_{sp}= specific humidity of air vapour mixture (g/kg)

H_R= relative humidity (%)

ρ_{ws} = density of water vapour (kg/m^3)

ρ = density of air (kg/m^3)

from equation (3.23), making ρ the subject of the formula

$$\rho = \rho_{ws}\left(\frac{0.622Hz}{H_{sp}}+1\right)$$ ------------------------(3.24)

Where,

Relative humidity, $H_r = \frac{\text{partial pressure of water vapour in air}}{\text{Vapour pressure of water at the same temperature}} \times \frac{100}{1}$ (Richardson et al, 1995) ------------------------(3.25)

Substituting (3.24) into (3.22)

$$\alpha = \frac{q}{zu}\left[1-\frac{RTH_{sp}}{u^2 v\rho_{ws}(0.622Hz+H_{sp})}\right]$$ ------------------------(3.26)

Substituting equation (3.26) into (3.17)

$$Li = 10\log\left[\frac{16p-\frac{pq}{2u}\left(1-\frac{RTH_{sp}}{u^2 v\rho_{ws}(0.622H_R+H_{sp})}\right)(16-Q)}{I_{ref}\Pi d^2\frac{q}{2u}\left(1-\frac{RTH_{sp}}{u^2 v\rho_{ws}(0.622H_r++H_{sp})}\right)}\right]-\log\left[\frac{dT}{d}\right]^2$$

------------------------(3.27)

If the wind blows with a velocity W in the direction of sound. (From assumption 4) then the resultant velocity of sound will be (u + w), the equation (3.27) now becomes;

$$li = 10\log\left[\frac{16p-\frac{pq}{2(u+w)}\left[1-\frac{RTH_{sp}}{(u+w)^2 v\rho_{ws}(0.622*Hz+H_{sp})}\right](16-Q)}{I_{ref}\Pi d^2\frac{q}{2(u+w)}\left(1-\frac{RTH_{sp}}{(u+w)^2 v\rho_{ws}(0.622Hz+H_{sp})}\right)}\right]-\log\left[\frac{dT}{d}\right]^2$$

--------------------(3.28)

Where

q = rate of cooling at constant volume of gas

w = wind speed (m/s)

p = power of machine (kW)

u = velocity of sound in air

T = temperature (^{0}K)

V= volume of gas flared (m^3)

Q = directivity factor

ρ = density of water vapour (kg/m^3)

R = specific gas constant

dT= total distance (m)

d= distance step length (m)

H_r= relative humidity

H_{sp} = specific humidity of air vapour mixture (kg/kg) equation (3.28) is the modelling equation for noise intensity level. Simulation of the modelling is obtained via computer programming using visual basic

CHAPTER FOUR

4.1 EXPERIMENTAL METHODOLOGY

4.1.1 THE MEASUREMENT OF ATMOSPHERIC TEMPERATURE

In measuring the atmospheric temperature, the mercury-in-glass thermometer is employed. It is placed in a Stevenson screen. When the atmospheric temperature increases, an expansion of mercury up the tube is observed. The extent of the expansion is read off the stem of the tube containing mercury. On the other hand, when there is a decrease in the atmospheric temperature, the mercury thread contracts down the tube and the extent of the contraction is read off the stem of the thermometer. Maximum temperatures were recorded with the thermometer when the mercury in the capillary tube expands thereby pushing a small metal index which remains at the highest temperature attained. Minimum temperatures are recorded with a spirit-in-glass thermometer. As the temperature falls, the alcohol thread moves backward along the tube and the metal index suspended inside the column of the spirit is dragged towards the bulb by the meniscus. The surface tension is sufficient to prevent the break through of the meniscus by the index, and when the temperature rises again the index remains at the lowest position attained.

4.1.2 THE MEASUREMENT OF WIND SPEED

Wind is the horizontal movement of air. The instrument used in measuring wind speed is called an anemometer. The anemometer consists of three or four semi-circular cups attached to the ends of horizontal spokes mounted on a high vertical spindle which makes it easier for measurement of the wind speed. As the concave sides offer greater resistance to the winds, the horizontal spokes will rotate and a central rod is moved which transmits the velocity (speed) of the wind in meters per second or miles per hour to an electrically operated dial. Mostly the speed recorded is not absolutely accurate. This is because after the wind has abated the rotation continues due to its own momentum.

4.1.3 THE MEASUREMENT OF RELATIVE HUMIDITY

Humidity is a measure of the dampness of the atmosphere which varies greatly from place to place at different times of the day. The relative humidity of the Niger-Delta area was measured using the hygrometer. This instrument consists of wet and dry bulb thermometers placed side by side in the Stevenson screen. The wet bulb is kept wet by a wick that dips into a reservoir of distilled water. When the air is not saturated, evaporation, which produces cooling, takes place from the moist wick. The wet-bulb therefore always shows a lower reading than the dry-bulb. From the measurement, a large difference, a high relative humidity. But if both have the same reading, it shows that relative humidity is 100 percent i.e. the air is saturated.

4.1.4 VOLUME OF GAS FLARED

The volumes of gas flared are collated from the log books of the four stations being considered. This value is the total volume of gas flared per month, and this is collated over a one year period.

These data are the monthly average collated over a one year period. The companies in the Niger-Delta area performed these experiments. The explanation of the experimental method to enhance understanding of the proposed modelling and to verify its validity.

4.1.5 MEASUREMENT OF NOISE INTENSITY LEVEL

The intensity of noise emanating from the flare station was measured using a sound level meter. The meter was placed at the required distance, which was measured using a measuring tape. The microphone of the equipment was adjusted to ensure that the incoming sound waves actuate temporary compression and rarefaction of air particles and then sets the diaphragm of the microphone on vibration. The vibration of the diaphragm is converted to a vibration in an electric current in the meter. The vibrations are in turn converted to a sound pressure level i.e. noise intensity reading on the meter, expressed in unit of measure called decibel (dB). The noise intensity readings were carried out for various distances of 20, 40, 60, 100m from the flare point and the results were recorded. The companies in the Niger-Delta area performed these experiments. The explanation of the experimental method to enhance understanding of the proposed modelling and to verify its validity. The results are shown below:

Table 4.1: Results of noise intensity measured for November 1997.

Stations	20 (m)	40 (m)	60 (m)	100 (m)
A	85.3	76.0	74.1	64.0
B	86.0	75.8	73.0	64.6
C	86.3	72.5	68.6	67.1
D	84.5	73.8	69.4	63.7

Table 4.2: Results of noise intensity measured for December 1997

Stations	20 (m)	40 (m)	60 (m)	100 (m)
A	86.8	74.5	69.8	61.2
B	82.8	76.4	64.7	63.2
C	83.4	73.2	68.6	66.9
D	82.8	72.4	64.7	65.7

Table 4.3: Results of noise intensity measured for January 1998

Stations	20 (m)	40 (m)	60 (m)	100 (m)
A	85.4	69.5	63.8	61.2
B	82.0	69.1	64.0	62.9
C	81.7	71.2	63.0	62.9
D	84.4	72.1	61.1	61.1

CHAPTER FIVE

5.1 EXPERIMENTAL DATA

EXPERIMENTAL DATA USED FOR THE SIMULATION OF NOISE INTENSITY LEVELS

STATION 1

Table 5.1a

Month	Volume of gas(m^3/s)	Wind speed W(m/s)	Surrounding temperature ^0C	Relative humidity Hr	Specific humidity H_{sp}	Density of water vapor ρ_{ws}
Jan	9.3053	2.80	36	80	1.67	0.0421
Feb	0.7584	2.20	36.5	63	1.35	0.0403
Mar	8.3466	2.90	36.2	80	1.69	0.0425
Apr	12.5803	1.39	35.0	85	1.69	0.401
May	16.0906	2.20	33.0	86	1.93	.0362
June	10.3049	1.81	30.0	90	1.33	0.0304
July	9.6075	1.80	34.6	90	1.74	0.0393
Aug	7.2855	1.39	33.5	91	1.67	0.0372
Sept	9.0678	2.88	33.2	89	1.59	0.0366
Oct	7.0740	2.78	34.0	87	1.64	0.0382
Nov	11.1565	1.38	32.0	88	1.48	0.0343
Dec	8.7081	1.28	35.0	82	1.63	0.0401

STATION 2

Table 5.2a

Month	Volume of gas(m^3/s)	Wind speed W(m/s)	Surrounding temperature ^{0}C	Relative humidity Hr	Specific humidity H_{sp}	Density of water vapor ρ_{ws}
Jan	0.4618	2.88	37.5	79	1.78	0.0452
Feb	0.4784	2.80	37.5	84	1.89	0.0452
Mar	0.4763	2.22	37.5	83	1.87	0.0452
Apr	0.0178	1.39	38.0	84	1.94	0.0464
May	0.0136	3.40	38.0	86	1.99	0.0464
June	0.0155	1.04	39.8	88	2.20	0.050
July	0.0078	1.41	34.2	89	1.72	0.039
Aug	0.0043	3.33	30.0	88	1.30	0.030
Sept	.0052	2.22	30.4	91	1.39	0.031
Oct	0.0146	2.78	31.0	90	1.42	0.0032
Nov	0.0836	1.38	33.0	87	1.35	0.036
Dec	0.0836	1.38	33.0	75	1.34	0.036

STATION 3

Table 5.3a

Month	Volume of gas(m^3/s)	Wind speed W(m/s)	Surrounding temperature ^0C	Relative humidity Hr	Specific humidity H_{sp}	Density of water vapor ρ_{ws}
Jan	0.3421	2.80	31.8	72	1.21	0.034
Feb	0.3243	2.20	37.0	76	1.67	0.044
Mar	0.38470	2.80	36.8	75	1.63	0.0436
Apr	0.0945	1.39	36.9	83	1.81	0.0438
May	0.0803	2.20	34.0	84	1.60	0.0382
June	0.0039	1.81	31.2	86	1.40	0.033
July	0.2318	1.50	33.0	90	1.60	0.036
Aug	0.2704	1.39	32.8	88	1.57	0.036
Sept	0.0276	2.78	31.0	91	1.44	0.032
Oct	0.1179	2.78	32.0	87	1.46	0.034
Nov	0.1530	1.38	34.0	86	1.62	0.038
Dec	0.2182	1.28	33.5	82	1.50	0.037

STATION 4

Table 5.4a

Month	Volume of gas(m^3/s)	Wind speed W(m/s)	Surrounding temperature ^0C	Relative humidity Hr	Specific humidity H_{sp}	Density of water vapor ρ_{ws}
Jan	0.0645	2.20	37.5	67	1.51	0.0452
Feb	0.2356	2.75	35.5	74	1.51	0.0411
Mar	0.0552	1.39	36.5	83	1.78	0.043
Apr	0.1779	1.28	33.5	84	1.54	0.0370
May	0.1984	1.75	32.0	85	1.44	0.0343
June	0.2645	2.0	33.6	88	1.63	0.0343
July	0.0318	1.94	31.0	90	1.33	0.0320
Aug	0.0027	1.38	30.0	90	1.33	0.030
Sept	0.0345	2.0	32.1	89	1.54	0.035
Oct	0.0874	1.38	33.0	89	1.59	0.036
Nov	0.2645	1.34	36.0	84	1.75	0.042
Dec	0.3161	2.60	34.1	77	1.45	0.038

CONSTANTS

Power of machine, P = (0.8 kW)

Directivity factor, Q = 1

Rate of cooling at constant volume of gas, q =2.6334×10^{-4}

Specific gas constant R = 0.287

Velocity of sound in air, U = 330 m/s

Density of air = 1.293 kg/m^3

Reference intensity, $I_{ref} = 10^{-9}$ kW/m^2

equipment (Blake, 1972) and different weather conditions. At low volume of flare, the process equipment is unbalanced which results in vibration. Sound is heard when the frequency of the vibration falls within the audible range for normal hearing ie 20 to 20,000Hz (consequently, the higher the volume of flares the more the stability of the machine and the lower the noise radiated; and vice versa). Also affecting the value of noise radiation is the weather condition of the flare station, some of which include the wind speed, ambient temperature, relative humidity etc. The weather has a fundamental influence on sound propagation outdoors. Errors of the order of 20dBA could be introduced if weather is not taken into account (Connell, 1972). Relative humidity is also an important factor in sound propagation, the more humid the air is, the faster sound waves travel in it (www.engineeringtoolbox.com). In summer, ambient temperature decreases with height causing sound waves to be refracted away from the earth; in winter, with temperature inversion, temperature increases with height and refraction takes place toward the earth causing the noise intensity to be increased rather than attenuated. The Niger-Delta area of Nigeria experiences both temperate and rainforest weather phenomena.

Experimental data of the present study indicate that the noise generated from gas flaring in the Niger-Delta is to some extent below the recommended limit by W.H.O, 1999 i.e. lower than 70dBA over 24 hours.

The variations between experimental and modelled simulation results can be attributed to the following factors (Odigure and Abdulkareem, 2001).

i) Experimental values are measure of noise intensity for the prevailing meteorogical condition as stated above. While the simulated results are instantaneous values i.e. they measure the possible amount of noise intensity that could be radiated during gas flaring at a given time.

ii) The variation in experimental and simulation values could be attributed to some assumptions made at the initial stage of modelling such as wind speed, temperature, pressure, heat conduction and weather condition. The assumption may not conform to prevailing atmospheric condition.

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5.1.1 Model Simulation Results

Table 5.1b: Noise Intensity for Station 1 For various months of the Year

Noise Intensity for Station 1 For various months of the Year

Distance	January	Febuary	March	April	May	June	July	August	September	October	November	December
0.0000	80.7085	80.7006	80.7098	80.6900	80.7006	80.6955	80.6954	80.6900	80.7095	80.7082	80.6899	80.6886
20.0000	75.2899	75.2821	75.2912	75.2715	75.2821	75.2770	75.2769	75.2715	75.2910	75.2897	75.2714	75.2700
40.0000	72.1203	72.1124	72.1216	72.1018	72.1124	72.1073	72.1072	72.1018	72.1213	72.1200	72.1017	72.1004
60.0000	69.8714	69.8635	69.8727	69.8529	69.8635	69.8584	69.8583	69.8529	69.8724	69.8711	69.8528	69.8515
80.0000	68.1270	68.1192	68.1283	68.1086	68.1192	68.1141	68.1139	68.1086	68.1280	68.1267	68.1084	68.1071
100.0000	66.7017	66.6939	66.7030	66.6833	66.6939	66.6888	66.6887	66.6833	66.7028	66.7015	66.6832	66.6819
120.0000	65.4967	65.4889	65.4980	65.4783	65.4889	65.4838	65.4836	65.4783	65.4977	65.4964	65.4781	65.4768
140.0000	64.4528	64.4450	64.4541	64.4344	64.4450	64.4399	64.4398	64.4344	64.4539	64.4526	64.4343	64.4330
160.0000	63.5321	63.5243	63.5334	63.5137	63.5243	63.5192	63.5190	63.5137	63.5331	63.5318	63.5135	63.5122
180.0000	62.7085	62.7006	62.7098	62.6900	62.7006	62.6955	62.6954	62.6900	62.7095	62.7082	62.6899	62.6886
200.0000	59.5388	59.5310	59.5401	59.5204	59.5310	59.5259	59.5257	59.5204	59.5399	59.5386	59.5202	59.5189
300.0000	57.2899	57.2821	57.2912	57.2715	57.2821	57.2770	57.2769	57.2715	57.2910	57.2897	57.2714	57.2700
400.0000	55.5455	55.5377	55.5468	55.5271	55.5377	55.5326	55.5325	55.5271	55.5466	55.5453	55.5270	55.5257
500.0000	54.1203	54.1124	54.1216	54.1018	54.1124	54.1073	54.1072	54.1018	54.1213	54.1200	54.1017	54.1004
600.0000	52.9152	52.9074	52.9165	52.8968	52.9074	52.9023	52.9022	52.8968	52.9163	52.9150	52.8967	52.8954
700.0000	51.8714	51.8635	51.8727	51.8529	51.8635	51.8584	51.8583	51.8529	51.8724	51.8711	51.8528	51.8515
800.0000	50.9506	50.9428	50.9519	50.9322	50.9428	50.9377	50.9376	50.9322	50.9517	50.9504	50.9321	50.9308
900.0000	50.1270	50.1192	50.1283	50.1086	50.1192	50.1141	50.1139	50.1086	50.1280	50.1267	50.1084	50.1071
1000.0000	49.3819	49.3741	49.3832	49.3635	49.3741	49.3690	49.3689	49.3635	49.3830	49.3817	49.3634	49.3621

Table 5.2b: Noise Intensity for Station 2 For various months of the Year

Noise Intensity for Station 2 For various months of the Year

Distance	January	Febuary	March	April	May	June	July	August	September	October	November	December
0.0000	80.7095	80.7085	80.7009	80.6900	80.7163	80.6854	80.6903	80.7154	80.7009	80.7082	80.6899	80.6899
20.0000	75.2910	75.2899	75.2823	75.2715	75.2978	75.2669	75.2718	75.2968	75.2823	75.2897	75.2714	75.2714
40.0000	72.1213	72.1203	72.1127	72.1018	72.1281	72.0973	72.1021	72.1272	72.1127	72.1200	72.1017	72.1017
60.0000	69.8724	69.8714	69.8638	69.8529	69.8792	69.8484	69.8532	69.8783	69.8638	69.8711	69.8528	69.8528
80.0000	68.1280	68.1270	68.1194	68.1086	68.1348	68.1040	68.1088	68.1339	68.1194	68.1267	68.1084	68.1084
100.0000	66.7028	66.7017	66.6942	66.6833	66.7096	66.6787	66.6836	66.7086	66.6942	66.7015	66.6832	66.6832
120.0000	65.4977	65.4967	65.4891	65.4783	65.5045	65.4737	65.4785	65.5036	65.4891	65.4964	65.4781	65.4781
140.0000	64.4539	64.4528	64.4453	64.4344	64.4607	64.4298	64.4347	64.4598	64.4453	64.4526	64.4343	64.4343
160.0000	63.5331	63.5321	63.5245	63.5137	63.5399	63.5091	63.5139	63.5390	63.5245	63.5318	63.5135	63.5135
180.0000	62.7095	62.7085	62.7009	62.6900	62.7163	62.6854	62.6903	62.7154	62.7009	62.7082	62.6899	62.6899
200.0000	59.5399	59.5388	59.5312	59.5204	59.5467	59.5158	59.5207	59.5457	59.5312	59.5386	59.5202	59.5202
300.0000	57.2910	57.2899	57.2823	57.2715	57.2978	57.2669	57.2718	57.2968	57.2823	57.2897	57.2714	57.2714
400.0000	55.5466	55.5455	55.5380	55.5271	55.5534	55.5225	55.5274	55.5525	55.5380	55.5453	55.5270	55.5270
500.0000	54.1213	54.1203	54.1127	54.1018	54.1281	54.0973	54.1021	54.1272	54.1127	54.1200	54.1017	54.1017
600.0000	52.9163	52.9152	52.9077	52.8968	52.9231	52.8922	52.8971	52.9221	52.9077	52.9150	52.8967	52.8967
700.0000	51.8724	51.8714	51.8638	51.8529	51.8792	51.8484	51.8532	51.8783	51.8638	51.8711	51.8528	51.8528
800.0000	50.9517	50.9506	50.9431	50.9322	50.9585	50.9276	50.9325	50.9575	50.9431	50.9504	50.9321	50.9321
900.0000	50.1280	50.1270	50.1194	50.1086	50.1348	50.1040	50.1088	50.1339	50.1194	50.1267	50.1084	50.1084
1000.0000	49.3830	49.3819	49.3744	49.3635	49.3898	49.3589	49.3638	49.3888	49.3744	49.3817	49.3634	49.3634

Table 5.3b: Noise Intensity for Station 3 For various months of the Year

Noise Intensity for Station 3 For various months of the Year

Distance	January	Febuary	March	April	May	June	July	August	September	October	November	December
0.0000	80.7085	80.7006	80.7085	80.6900	80.7006	80.6955	80.6900	80.6900	80.7082	80.7082	80.6899	80.6886
20.0000	75.2899	75.2821	75.2899	75.2715	75.2821	75.2770	75.2715	75.2715	75.2897	75.2897	75.2714	75.2700
40.0000	72.1203	72.1124	72.1203	72.1019	72.1124	72.1074	72.1019	72.1018	72.1200	72.1200	72.1017	72.1004
60.0000	69.8714	69.8635	69.8714	69.8530	69.8635	69.8585	69.8530	69.8529	69.8711	69.8711	69.8528	69.8515
80.0000	68.1270	68.1192	68.1270	68.1086	68.1192	68.1141	68.1086	68.1086	68.1267	68.1267	68.1084	68.1071
100.0000	66.7017	66.6939	66.7017	66.6833	66.6939	66.6888	66.6833	66.6833	66.7015	66.7015	66.6832	66.6819
120.0000	65.4967	65.4889	65.4967	65.4783	65.4889	65.4838	65.4783	65.4783	65.4964	65.4964	65.4781	65.4768
140.0000	64.4528	64.4450	64.4528	64.4344	64.4450	64.4399	64.4344	64.4344	64.4526	64.4526	64.4343	64.4330
160.0000	63.5321	63.5243	63.5321	63.5137	63.5243	63.5192	63.5137	63.5137	63.5318	63.5318	63.5135	63.5122
180.0000	62.7085	62.7006	62.7085	62.6900	62.7006	62.6955	62.6900	62.6900	62.7082	62.7082	62.6899	62.6886
200.0000	59.5388	59.5310	59.5388	59.5204	59.5310	59.5259	59.5204	59.5204	59.5386	59.5386	59.5202	59.5189
300.0000	57.2899	57.2821	57.2899	57.2715	57.2821	57.2770	57.2715	57.2715	57.2897	57.2897	57.2714	57.2700
400.0000	55.5455	55.5377	55.5455	55.5271	55.5377	55.5326	55.5271	55.5271	55.5453	55.5453	55.5270	55.5257
500.0000	54.1203	54.1124	54.1203	54.1019	54.1124	54.1074	54.1019	54.1018	54.1200	54.1200	54.1017	54.1004
600.0000	52.9152	52.9074	52.9152	52.8968	52.9074	52.9023	52.8968	52.8968	52.9150	52.9150	52.8967	52.8954
700.0000	51.8714	51.8635	51.8714	51.8530	51.8635	51.8585	51.8530	51.8529	51.8711	51.8711	51.8528	51.8515
800.0000	50.9506	50.9428	50.9506	50.9322	50.9428	50.9377	50.9322	50.9322	50.9504	50.9504	50.9321	50.9308
900.0000	50.1270	50.1192	50.1270	50.1086	50.1192	50.1141	50.1086	50.1086	50.1267	50.1267	50.1084	50.1071
1000.0000	49.3819	49.3741	49.3819	49.3635	49.3741	49.3690	49.3635	49.3635	49.3817	49.3817	49.3634	49.3621

Table 5.4b: Noise Intensity for Station 4 for various months of the Year

Noise Intensity for Station 4 For various months of the Year

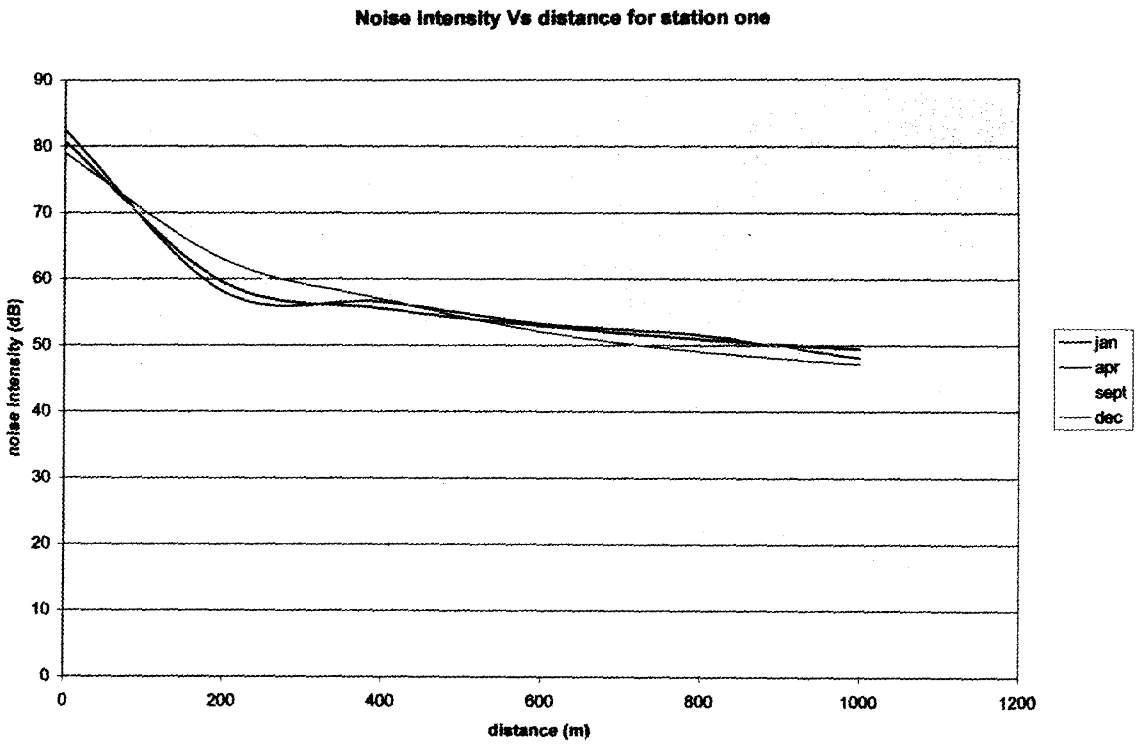
Distance	January	Febuary	March	April	May	June	July	August	September	October	November	December
0.0000	80.7006	80.7078	80.6900	80.6886	80.6948	80.6980	80.6972	80.6899	80.6980	80.6899	80.6894	80.7059
20.0000	75.2821	75.2893	75.2715	75.2700	75.2762	75.2795	75.2787	75.2714	75.2795	75.2714	75.2708	75.2873
40.0000	72.1124	72.1196	72.1018	72.1004	72.1066	72.1098	72.1090	72.1017	72.1098	72.1017	72.1012	72.1177
60.0000	69.8635	69.8707	69.8529	69.8515	69.8577	69.8609	69.8601	69.8528	69.8609	69.8528	69.8523	69.8688
80.0000	68.1192	68.1263	68.1086	68.1071	68.1133	68.1166	68.1158	68.1084	68.1165	68.1084	68.1079	68.1244
100.0000	66.6939	66.7011	66.6833	66.6819	66.6880	66.6913	66.6905	66.6832	66.6913	66.6832	66.6826	66.6991
120.0000	65.4889	65.4960	65.4783	65.4768	65.4830	65.4863	65.4855	65.4781	65.4862	65.4781	65.4776	65.4941
140.0000	64.4450	64.4522	64.4344	64.4330	64.4391	64.4424	64.4416	64.4343	64.4424	64.4343	64.4337	64.4502
160.0000	63.5243	63.5314	63.5137	63.5122	63.5184	63.5217	63.5209	63.5135	63.5216	63.5135	63.5130	63.5295
180.0000	62.7006	62.7078	62.6900	62.6886	62.6948	62.6980	62.6972	62.6899	62.6980	62.6899	62.6894	62.7059
200.0000	59.5310	59.5382	59.5204	59.5189	59.5251	59.5284	59.5276	59.5202	59.5284	59.5202	59.5197	59.5362
300.0000	57.2821	57.2893	57.2715	57.2700	57.2762	57.2795	57.2787	57.2714	57.2795	57.2714	57.2708	57.2873
400.0000	55.5377	55.5449	55.5271	55.5257	55.5318	55.5351	55.5343	55.5270	55.5351	55.5270	55.5264	55.5429
500.0000	54.1124	54.1196	54.1018	54.1004	54.1066	54.1098	54.1090	54.1017	54.1098	54.1017	54.1012	54.1177
600.0000	52.9074	52.9146	52.8968	52.8954	52.9015	52.9048	52.9040	52.8967	52.9048	52.8967	52.8961	52.9126
700.0000	51.8635	51.8707	51.8529	51.8515	51.8577	51.8609	51.8601	51.8528	51.8609	51.8528	51.8523	51.8688
800.0000	50.9428	50.9500	50.9322	50.9308	50.9369	50.9402	50.9394	50.9321	50.9402	50.9321	50.9315	50.9480
900.0000	50.1192	50.1263	50.1086	50.1071	50.1133	50.1166	50.1158	50.1084	50.1165	50.1084	50.1079	50.1244
1000.0000	49.3741	49.3813	49.3635	49.3621	49.3682	49.3715	49.3707	49.3634	[illegible]	[illegible]	[illegible]	[illegible]

13) www.ecotopics.com **"special for ecotopics" by Abiodun Raufu.**

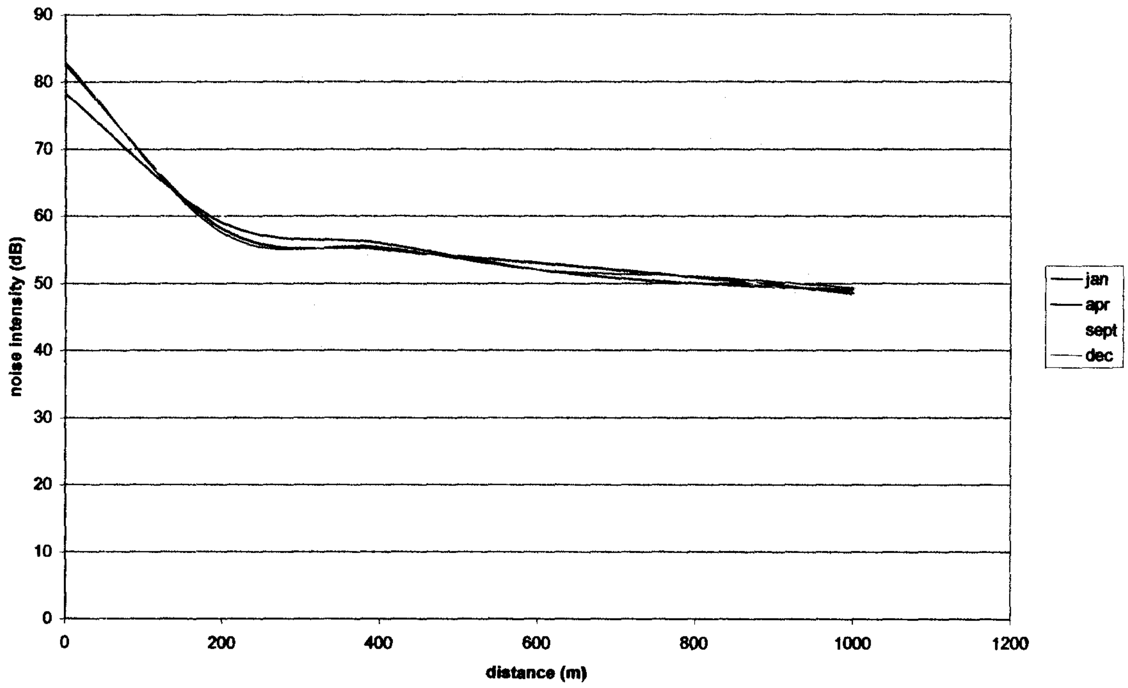
14) www.engineeringtoolbox.com

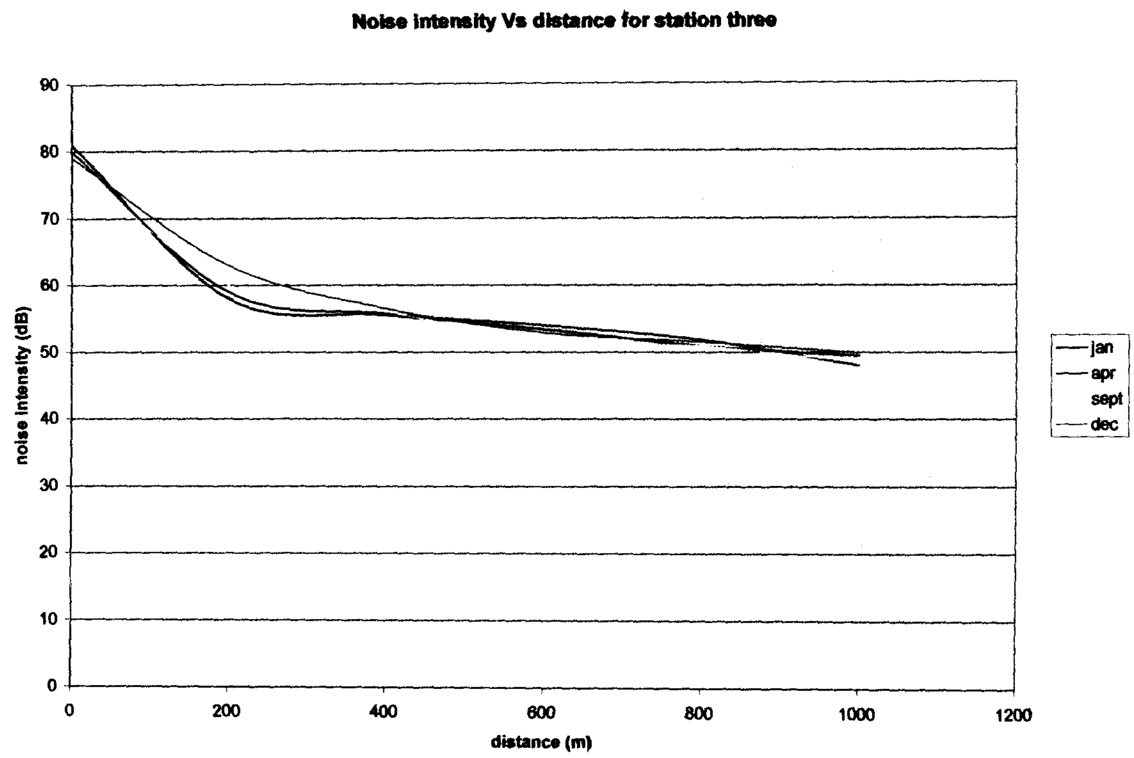
15) www.peacemagazine.org **"The bitter honey of the Niger-Delta" by Charles Soeze**

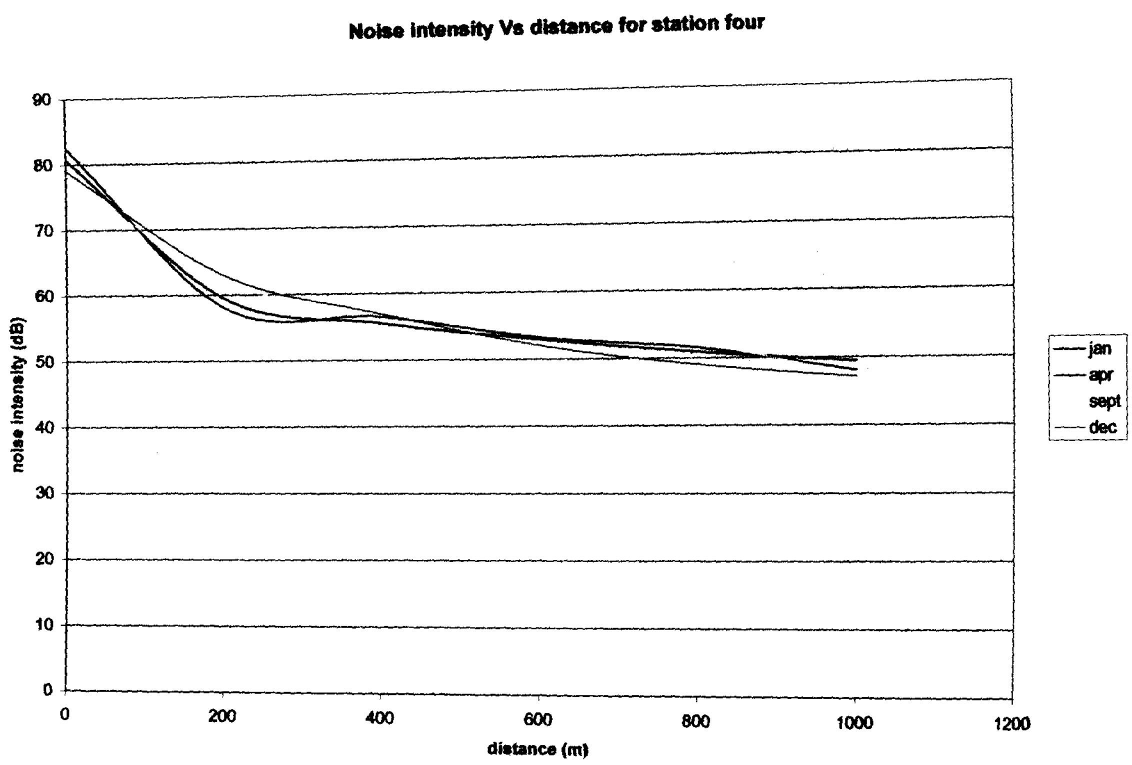
APPENDIX A GRAPH



Noise intensity Vs distance for station two




Noise intensity Vs distance for station three
noise intensity (dB)
distance (m)
0
10
20
30
40
50
60
70
80
90
0
200
400
600
800
1000
1200
jan
apr
sept
dec


Noise intensity Vs distance for station four
noise intensity (dB)
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
distance (m)
jan
apr
sept
dec

```
    T_ = (Val(T(ju%)) + 273)
    Hr_ = Val(Hr(ju%))
    Hsp_ = Val(Hsp(ju%))
    Dw_ = Val(Dw(ju%))

    Iref_ = (Val(Iref(0)) * 10 ^ 5)
    dT_ = Val(dT(0))
    P_ = Val(P(0))

    x = 0.1
    For row = 0 To 0
        y = x
        z = x
        answer(row, 0) = Li
        x = x + 20
    Next row
    x = 20
    For row = 1 To 9
        y = x
        z = x
        answer(row, 0) = Li
        x = x + 20
    Next row
    x = 200
    For row = 10 To 19
        y = x
        z = x
        answer(row, 0) = Li
        x = x + 100
    Next row
    getValues = 0
End Function
Private Sub textFlds()
    V(0).Left = station(0).Left + station(0).Width + 400
    W(0).Left = V(0).Left + station(0).Width + 200
    T(0).Left = W(0).Left + station(0).Width + 200
    Hr(0).Left = T(0).Left + station(0).Width + 200
    Hsp(0).Left = Hr(0).Left + station(0).Width + 200
    Dw(0).Left = Hsp(0).Left + station(0).Width + 200
    'Cps(0).Left = hs(0).Left + hs(0).Width + 200


    V(0).Top = station(0).Top
    W(0).Top = station(0).Top
    T(0).Top = station(0).Top
    Hr(0).Top = station(0).Top
    Hsp(0).Top = station(0).Top
    Dw(0).Top = station(0).Top
    'Cps(0).Top = station(0).Top

    For i% = 1 To 3
        Load Check1(i%)
        Check1(i%).Visible = True
        Check1(i%).Top = station(i%).Top


        Load V(i%)
        V(i%).Left = V(i% - 1).Left
```

```
        V(i%).Top = station(i%).Top
        V(i%).Visible = True

        Load W(i%)
        W(i%).Left = W(i% - 1).Left
        W(i%).Top = station(i%).Top
        W(i%).Visible = True

        Load T(i%)
        T(i%).Left = T(i% - 1).Left
        T(i%).Top = station(i%).Top
        T(i%).Visible = True

        Load Hr(i%)
        Hr(i%).Left = Hr(0).Left
        Hr(i%).Top = station(i%).Top
        Hr(i%).Visible = True

        Load Hsp(i%)
        Hsp(i%).Left = Hsp(0).Left
        Hsp(i%).Top = station(i%).Top
        Hsp(i%).Visible = True

        Load Dw(i%)
        Dw(i%).Left = Dw(0).Left
        Dw(i%).Top = station(i%).Top
        Dw(i%).Visible = True

    Next i%

    'Dim we As Integer
    'For we = 1 To 3
    '    Check1(we).Value = 0
    'Next we


End Sub

Private Sub setTitle()
    Dim title(22) As String
    Dim ex As Integer
    title(0) = "Input Data"
    title(1) = "Volume"
    title(2) = "W"
    title(3) = "T"
    title(4) = "Rel. H"
    title(5) = "Sp. H"
    title(6) = "Dw"

    title(7) = "Cps"
    title(8) = "D_a"

    title(9) = "CO2"
    title(10) = "CO"
    title(12) = "SO2"
    title(13) = "NO2"
    title(14) = "THC"
```

```
    title(15) = "L"
    title(16) = "Cps"
    title(17) = "I_dy"
    title(18) = "I_dz"
    title(19) = "J_dy"
    title(20) = "J_dz"
    title(21) = "K_dy"
    title(22) = "K_dz"

    ex = 1
    Load labTitle(ex)
    labTitle(ex).Caption = title(ex)
    labTitle(ex).Left = labTitle(ex - 1).Left + labTitle(ex -
1).Width + 400
    labTitle(ex).Top = labTitle(ex - 1).Top
    labTitle(ex).Visible = True


    For i% = 2 To 6
        Load labTitle(i%)
        labTitle(i%).Caption = title(i%)
        labTitle(i%).Left = labTitle(i% - 1).Left + labTitle(i%
- 1).Width + 200
        labTitle(i%).Top = labTitle(i% - 1).Top
        labTitle(i%).Visible = True
    Next i%

End Sub

Private Sub addComboItems()
    month.AddItem "January"
    month.AddItem "February"
    month.AddItem "March"
    month.AddItem "April"
    month.AddItem "May"
    month.AddItem "June"
    month.AddItem "July"
    month.AddItem "August"
    month.AddItem "September"
    month.AddItem "October"
    month.AddItem "November"
    month.AddItem "December"

End Sub

Private Sub simulate_Click()
    On Error GoTo mineError

retry:
    Dim select_, chec As Integer
    select_ = sel(month.Text)
    selMonth = month.Text
    If select_ = 0 Then
        'Do Nothing
    Else
        Dim j As Integer
        For j = 0 To 3
```

```
            If (Check1(j).Value = 1) Then
            chec = j
            getValues (j)
            vol = V_
            MsgBox "Sim Complete: Volume = " & vol
            whatsta = Str$(chec + 1)
            Set bisi(select_) = New Concent
            Load bisi(select_)
            bisi(select_).Show
            ElseIf (Check1(j).Value = 0) Then
                'Do Nothing
        End If
        Next j

    End If
    Exit Sub
        select_ = sel(month.Text)
    If select_ = 0 Then
        'Do Nothing
    Else
    End If

mineError:
    Dim response As Integer, Description As Integer
    Description = vbExclamation + vbRetryCancel
    response = MsgBox(Err.Description & ": Invalid Data!!!",
Description, "Invalid Data Error")
    If response = vbRetry Then
        Resume retry
    End If
End Sub
Private Function sel(mon As String) As Integer
    'ReDim bisi(12) As January
    selMonth = mon
    Select Case mon
        Case "January"
            sel = 1
        Case "February"
            sel = 2
        Case "March"
            sel = 3
        Case "April"
            sel = 4
        Case "May"
            sel = 5
        Case "June"
            sel = 6
        Case "July"
            sel = 7
        Case "August"
            sel = 8
        Case "September"
            sel = 9
        Case "October"
            sel = 10
        Case "November"
            sel = 11
        Case "December"
```

```
            sel = 12
        Case Else
            sel = 0
            MsgBox "Invalid Month Selected", vbExclamation,
"Trouble!"
    End Select
End Function

Private Function Li() As Double
    Dim f1, f2, f3, f4, fun As Double
    Dim q, U, R, Q_ As Double
    q = 2.6334 * 10 ^ -4
    U = 330
    R = 0.287
    Q_ = 1
    f2 = 1 - (R * T_ * Hsp_) / (((U + W_) ^ 2) * V_ * Dw_ *
(0.622 * Hr_ * Hsp_))
    f1 = 16 * P_ - (P_ * q / (2 * (U + W_))) * f2 * (16 - Q_)
    f3 = Iref_ * 3.142 * x ^ 2 * q / (2 * (U + W_)) * f2
    Li = 10 * Log10(f1 / f3) - Log10((dT_ / x) ^ 2)
End Function
Private Function Log10(func As Double) As Double
    Log10 = (Log(func) / Log(10))
End Function
Private Sub Command1_Click()
    callMonth
End Sub
```