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DETERMINISTIC MODEL FOR AIR POLLUTION CONCENTRATION MEASUREMENT

A CASE STUDY OF NIGER-DELTA AREA (CALABAR)

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CERTIFICATION

This is to certify that this research project titled "Deterministic Model for Air Pollution Concentration, A Case Study of Niger-Delta Area, (Calabar)" was carried out by **THOMAS FESTUS (98/7868EH)** was supervised, moderated, and approved by the following under-listed persons on behalf of the Chemical Engineering Department, School of Engineering and Engineering Technology Minna, Nigeria.

17/11/2004

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DECLARATION

I do hereby declare that this was wholly presented by me Thomas Festus under the close supervision of Engr. A. SAKA, of the Chemical Engineering Department, Federal University of Technology Minna, Niger State. And has never to my knowledge been submitted elsewhere

THOMAS FESTUS **DATE**

DEDICATION

This work is dedicated to the source and sustainers of all potential, Alpha and Omega, the Almighty God.

Also, specially dedicated to my beloved parents late Mr and Mrs Thomas K . Late Aunt Ruth S. Dowang who couldn't see the end of the academic race, who were always been there for me financially, and to encourage me over my education.

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ABSTRACT

The world technological system is growing faster thereby causing atmospheric pollution consistently. As a result of activities that are carried out daily in our environment, it leads to air pollution, which quite different from one place to another it causes hazardous effect to the entire ecosystem. The aim of this project is to develop a predictive model to determine the extent of gaseous pollutants concentration, which changes with meteorological data that are available From the simulated result, it is observed that the pollutants concentration (kg/m^3.) decrease with increase in altitudes, hz (m). The model was developed to obtain equation relating pollutant concentration with pressure, humidity, temperature and wind speed

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NOTATIONS , SYMBOLS AND ABBREVIATIONS

T	Temperature (K)
t	Temperature (^{0}c)
Ps	Saturation vapour pressume (mbar)
P	Pressure of air (mbar)
Ug	Wind velocity (in/s)
(X,Y,Z)	Dimensional field (m)
Q	Quantity of pollutant released (kg day)
Co	Initial concentration
ρ	Air density (kg/m^3)
U	Wind speed m/s
h_Z	Height difference (m)
H	Humidity (%)
V	Volume (m^3)
n	Number of moles
Hb	Haemoglobin
Hf	Hydrogen fluoride
Atm	Atmosphere
PAN	Peroxyacetyl nitrate
NMC	National meteorological centre
WHO	World health organization
CFC	Chlorofluoro carbon
Hcfc	Hydrogenated chloroflurocarbon

CHAPTER ONE

1.0 INTRODUCTION:

Pollution is the process of polluting (i.e to make impure) the available water resources, air, atmosphere, land etc (Azeez, 2001). Pollution is a by-product of human activities starting from premature agricultural farming technology to day's high agricultural technology industrial activities Industrialization is highly desirable for the substance of a nation's economy and the enhancement of the citizenry's well being. However, the negative impacts precipitated by the introduction of its unwanted by products into the ecological systems may be catastrophic, if allowed to build up and uncontrolled. Hence, the need to consider environmental problems during design and operation of chemical process industries (Meetan, 1981)

Point sources are source that have a specific location These include chemical plants, steel mills, oil refineries, and hazardous waste incinerators (Colvile, 1990) Pollution can be released when equipment leaks, when material is transferred from one area to another, or when waste is given off from a facility through smoke-stake (Scaperdas, 1990)

Area sources of toxic air pollutants are made up of many smaller sources releasing pollutants to the outdoor air in a defined area examples include automobiles, neighbourhood dry cleaners, small metal plating operations, gas stations and wood stoves (Azeez, 2001) The automobiles, industry and electric power plants are the main sources of air pollutants from man controlled processes Volcanic action, forest fires and dust storm are natural sources of air pollutants, but these contribute little compared to the man-made sources (Olabanji, 2003). The principal sources of emission in Cross River State (Calabar) are transportation (combustion of fuel), refinery, oils and distillate, evaporation during transfer and storage. Industrial uses, wood (fuel and forest burning), incineration (Olabanji, 2003). The major pollutants are gases and particulate matters gases such as oxides of sulphur, nitrogen and carbon, ammonia and hydrocarbons Other pollutants are particulate matters such as smoke, dust, fog, must etc (George 2000)

Calabar metropolis as an industrial city is being faced with most of these air pollution problems, which is as a result of the production of different product which include the conversion of raw materials into finished goods because of the location of these industries which is not far from the residential area. In Calabar, the principal source of their pollution is transportation, which brought about combustion of fuel, and forest burning and also solvent evaporation Other pollutants are - Carbon monoxides (CO), hydrogen sulphide (H_2S), hydrocarbons and particulate matters Therefore, through the modern development of techniques and near perfect strategy of controlling these air pollution hazards, ones health, wildlife, plants, animals, and costs could be save from total damage (Olabanji, 2003).

A critical area shows that the habitants of the area are exposed to a lot of hazard, due to the in ability of government and process industries to quantify the resultant effect of environmental pollution on the people at Niger-Delta area. It was on time bases that a mathematical model that will predict the change in concentration of pollution in air due to metrological changes would be developed.

Model is a simplified representation of a system intended to enhance our ability to understand, explain, change preserve, predict and possible control the behaviour of a system (Naelamkavil 1987) Modelling is thus, the process of establishing, interrelation between important entities of a system Models are represented in term of goods, performance criteria and constraints (Jamen and Donald) Mathematical model of a system only represent the mathematical aspect of a process or system of interest. A model retain the physical properties of the system, it is therefore aimed at providing the simplest possible description of a system which is an exact scaled down replica of the prototype and at the same times retain it physical characteristics (William, 1990).

Simulation; Martin Shubik defines simulation of a system as the operation of a model, which is a representation of the system, the model being amendable to manipulation, which would be impossible too expensive or impracticable to perform on the system it portrays Simulation is used on the principal reasons:-

1) To give greater understanding and insight into the behaviour and this physical system and principle up which its design is based.
2) To prove a convenient, inexpensive and time saving means of gaining this understanding and insight under a variety of operation condition.

1.1 AIMS AND OBJECTIVES

1) The collation of data on meteorological conditions i.e. Temperature, pressure, wind and relative humidity. To develop a model to determine the concentration of pollutant in the air in Niger-Delta Area (Calabar).

2) To simulate the model developed by computer programme using visual basic

1.2 SCOPE OF STUDY

This research work covers the various air pollutants in the Niger- Delta Area (e.g. Calabar) and how a mathematical model can be used to determine the concentration of the air pollutants, which will be more economical compared to the experimental method

1.3 JUSTIFICATION

The advancement being made in science and technology and indeed chemical engineering today are contributing immensely to continued global industrial growth and development

The following people have carried out research on modelling of air pollution concentration. (George, 2000), (Olabanji, 2003). This research is concerned with identifying and quantifying the pollutants emission, pollutants concentrations and human exposure. This requires a combination of measurement and modelling.

As Chemical Engineers, great importance must be attached to the economic implications as well as safety and health in relation to the community expectations.

CHAPTER TWO

2.0 LITERATURE REVIEW

Air pollution is the destruction of the purity of the ambient air Air pollution turns clear. odourless air into hazy smelly air that harms health kills plants and damages physical infrastructures Man causes air pollution by pouring hundreds of millions of tons of gases and particulates into the atmosphere each year (Koutitas, 1998).

Most air pollution results from combustion processes The burning of gasoline to power motor vehicles and the burning of coal to heat buildings and manufacture products are examples of such processes. Each time fuel is burnt in a combustion process some types of pollutants are released into the air. The air pollutants ranges from small amount to colourless poisonous gas to cloud of thick smoke (George, 2000).

The environmental problems range from damage to crop and vegetation, to increase acidity of lakes that make them inhabitable for fish and other aquatic life Air pollution, if not checked could lead to disastrous pollution problem, affecting the global planet and could cause destruction to the ecosystem and loss of many species on earth The increase in global population and the associated industrialization, urbanization and motorization has inevitably led to a greater demand for energy Production and consumption of both renewable and non-renewable energy has increased steadily since the last century (Olabanji, 2003). Historical monitoring of sediments and soils demonstrates how the rise in coal production since the industrial revolution has lead to a rise in certain pollutant emissions. Europe, North America and the former USSR account for 20 percent of the world population. Yet in 1998 they consumed 68 percent of total primary energy (David, 1996)

The combustion of fossil fuels for electricity generation, industrial processes, transport and space heating is the predominant source of primary pollutants in the world Industrial processes, such as smelting of metal and refining of all account for a significant proportion of primary pollutant emission there are several air pollutants which result from the discharge of toxic substance, accounting to the report of WHO, there are five major pollutants that are constantly discharge into the air and they are; sulphur-dioxide, carbon-dioxide, hydrocarbons, nitrogen oxide and particulate matters (Olabanji, 2003). These Pollutants are obtained from burning agricultural land. combustion process etc. Carbon monoxide results from incomplete combustion of fuel in automobile engine Sulphur dioxide result from the burning of coal oil both in utility and industrial plants Petroleum refining is also a major source of SO_2 The particulate matters include. soot. asbestos. dust. leaf which may vary in sizes ranging from the visible to the microscopic components sources of hydro carbon include; the evaporation of industrial solvent, as well as emission from internal combustion engine, using liquefied petroleum products such as gasoline while the harmful nitrogen oxide result from transportation vehicles, industrial boiler from plant etc (Warner, 1996)

Pollutant depends on such weather conditions as temperature, wind speed, and the movement of high and low pressure systems and their interaction with the local topography, for example, mountains and valleys. Normally, temperature decreases with altitude But when a colder layer of air settles under a warm layer, production of temperature or thermal inversion. atmospheric mixing is retarded and pollutants may accumulate near the ground Inversions can become sustained under a stationary higher-pressure system coupled with low wind-speeds (Wadden, 1997)

Often, the first noticeable effects of pollution are aesthetic and may not necessary be dangerous. These include visibility reduction due to tiny particles suspended in air, or bad odours, such as the rotten egg smell produced by hydrogen sulphide emanating from pulp and paper mills Large-scale effect can be caused from tall flare and smoke stacks used by industries and utilities do not remove pollutants but simply boost them higher into the atmosphere, there by reducing their concentration at the site. There pollutants may then be transported over large distance and produce adverse effect in areas far from the site of the original emission Sulphur dioxide and nitrogen oxide emissions from the Central and Eastern U.S are causing acid rain in New York State, New England, and Eastern Canada. The PH level, or relative acidity of many freshwater lakes in that region have been altered, so dramatically by this rain that entire fish population have been destroyed Similar effects have been observed in Europe. Sulphur dioxide emissions and the subsequent formation of sulphuric acid can also be responsible for the attack on limestone and marble at large distances from the source (Wadden, 1997).

2.2 Air Pollution

Many of our activities introduce undesirable substances known as pollutants into the air Within limits some natural processes can remove the pollutants. How ever, industrialization has causes a tremendous increase in the release of pollutants into the air (Steve, 1999) In many places, these pollutants are present in concentrations that cause harm to human, animal and plant life and to property such as change in air, where it is made impure is known as air pollution The long list of health problems caused or aggravated by air pollution includes; Lungs diseases, such as chronic bronchitis and pulmonary emphysema, cancer, particular lungs cancer, natural disorders, including brain damage, bronchial asthma and the common cold, which are most persistent with lightly polluted air and eye irritation (Alphonsus; 2000). The environmental problems ranges from damage to crops and vegetation, to increased acidity of lakes that make them uninhabitable for fish and other aquatic life. Air pollution, if not checked, could lead to disastrous pollution problem, affecting the global planet and could cause destruction to eco-system and the loss of many species on earth (Pius, 2001)

2.2.1 Causes of Air Pollution

The main cause of air pollution is the combustion of fossil fuels such as, coal, petrol, gasoline and gasses. Most factories, power plants, vehicles, trains and aircraft use fossil fuels to obtained energy. In the process, much pollution is released into the air Other causes of pollution include the release of freons from aerosol cans and poisonous gases from chemical warfare

2.2.2 Pollutants

The main air pollutants are as follows:(Shaba, 2003).

i. Particulate matter (tiny solids)

ii. Oxides of carbon

iii. Oxides of sulphur and Nitrogen

iv. Gaseous hydrocarbons and chlorofluorocarbons

2.2.2.1 Particulate Matter

Smoke, soot, and dust are emission mainly by industrial processes, the burying of coal and wood fires (George, 2000). They damage the respiratory system, especially the lungs Another very poisonous solid pollutant is lead and lead (iii) bromide, which is emitted in the exhaust of motorcars using leader petrol. Lead dust can cause lead poisoning and injury to the nervous systems. The lead that is inhaled accumulates in the body. Over a long period, the amount of accumulated lead reaches levels that are toxic to the body. Poisonous by-products from industrial suspended particles or aerosol includes dust, smoke, and fog (David, 1996)

2.2.2.2 Oxides of Carbon

Carbon oxides are colourless, odourless and poisonous gas. It is produced in large amounts when the carbon in fuel is burnt incompletely. Carbon ii oxide, if inhaled, competes with oxygen for the haemoglobin in the blood (Olabanji, 2003). This causes a reduction in the amount of oxygen that is carried to the body tissues. A carbon oxide concentration of 0.05% in the atmosphere could prolong the period and cause brain damages. At lower concentration carbon monoxide causes dizziness, headache and fatigue (James, 1999).

2.2.2.3 Oxides of Nitrogen and Sulphur:

Oxides of sulphur are acidic, corrosive and poisonous. When sulphur-containing coal is burnt it give off sulphur (iv) oxide. Most of the sulphur (iv) oxide comes from electric power station and industrial plants (Shaba, 2003). Oxides of nitrogen are produced when combustion of fuels occurs at high temperature. The major sources of these pollutions (e.g. NO, NO_2) are from exhaust of transportation vehicles (Pius, 2001). Oxides of sulphur and nitrogen dissolve in rainwater to produce acids. This result in the fall of acid rain, which is harmful to plant and animal life, building and metal structures. Oxides of nitrogen react with sunlight to produce secondary pollutant such as - Ozone, nitrogen IV oxides and alkanals. These together with the solid pollutants and water droplets in air, from the constituents and water oxides of nitrogen and sulphur cause irritation of the eyes, nose, throat and respiratory tissues (Thomas, 2000).

2.2.2.4. Hydrocarbons

These are released into the air when fuels evaporate from storage tanks. They are also found in the exhaust of motor vehicles when fuel is burnt incompletely. Many hydrocarbons are believed to cause cancer by reacting with nitrogen oxides in the presence of light, they tend to produce smog or heavily stagnate air (Steve, 1999).

2.2.2.5 Chlorofluorocarbons (CFCS)

These are group of man-made chemicals such as freons, which are used as propellants for spray cans, coolants in refrigerators and air conditioners, and for making plastic foams In the upper atmosphere, the ultraviolet light break off a free chlorine atom (Cl), from chlorofluorocarbons molecule The free chlorine atom is very reactive and attacks a molecule of Ozone O_3, to produce an ordinary oxygen molecule O_2, and unstable oxides of chlorine (Cl) The latter readily react with atomic oxygen O to form an oxygen molecule O_2 and release the chorine atom, which then attacks another Ozone molecules (George, 2000) Thus, the process is repeated many times causing depletion in the Ozone layer The Ozone layer is important because it acts as shield preventing ultraviolet light from reaching the earth surface A diminishing ozone layer means an increase in the level ultraviolet radiation that reaches the earth This posses a danger to human health and which causes increase in cataract, skin cancer and sun burns, it may also damage our body defence system, thus lowering our resistance to diseases (Olabanji, 2003)

2.2.3 Gaseous Pollutants

Gaseous pollutants may be classified as inorganic or organic pollutants Inorganic pollutants consist of the following (Alphonsus, 2000)

1) Sulphur Gases Sulphur dioxide, sulphur trioxide, hydrogen sulphide
2) Nitrogen Gases Nitrous oxide, nitric oxide, Nitrogen dioxide, other nitrous oxides
3) Oxides of Carbon Carbon dioxide, carbon monoxide
4) Cyanides Hydrogen cyanide
5) Ammonium Compound Ammonia
6) Halogen halides Hydrogen fluoride, hydrogen chloride, chlorine, fluorine, silicontetrafluoride
7) Photochemical product Ozone, oxidants
8) Chlorofluorocarbons 1 1 1-trichol-2, 2,2-trifluoroethane, trichlorofluorome-thane, dichlorodifluoromethane, 1,2-dichloro1, 1,2,2-tetrafluoroethane, chloro-Pentrafluoroethane

Organic pollutants consist of (Shaba, 2003)

1. Hydrogen carbons
    a. Paraffin's, Methane, ethane, octane
    b. Acetylene
    c. Olefins. Ethylene, butadiene
    d. Aromatics. Benzene, toluene, benzpyrene, xylene, styrene
2. Aliphatic Oxygenated Compounds
    a. Aldehydes. Formaldehyde
    b. Ketones. Acetone, methylethy Ketone
    c. Organic acids
    d. Alcohols. Methanol, ethanol, Isopropanol
    e. Organic halides. Cyanogenchloride bromobenzyl cyanide
    f. Organic sulphides. Dimethyl sulphide
    g. Organic hyfroperoxides. Peroxyacetyl nitric or nitrate (PAN)

The most common gaseous pollutants and their major sources and significance are shown in the table below (Shaba, 2003):

Table:2.1

Air Pollutants	**From Manufacturing Sources Such as these**	**In Typical industries**	**Cause these damaging Effect**
Alcohols	Used as solvent in coatings	Surface coating	Sensory and respiratory irritation
Aldehydes	Results from thermal decomposition of fats, oil, or glycerol: used in some glues and binder	Food processing light process, wood furnit-ture, clip board	An irritation odour, suffocating, pungent, choking not immediately dangerous to life; can become in tolerable in a very short time
Ammonia	Used in refrigeration, chemic-al process such as dye making explosives, lacquer, fertilizer	Textile, chemicals	Corrosive to copper, brass, aluminium & zinc high concentration producing chemical burns on wet skin

Aromatics	Used as solvent in coatings	Surface coating printing	Irritation of mucus membrane, narcotic effects Some are carcinogens
Arsine	Any soldering, picking, etching or plating process involving metals or acid containing arsenic	Chemical processing, smelting	Breakdown of red cells in blood
Carbon Dioxide	Fuel combustion cracking	Industrial boilers, Cement and lime production	Green house gas
Carbon monoxide	Fuming of metallic oxides, gas-operated fork trucks	Primary metals, steel and aluminium	Reduction in oxygen carrying capacity of blood
Chlorine	Manufactured by electrolysis, bleaching cotton and for; by-product of organic compound	Textiles, chemicals	
Chlorofluorocarbons	Used in refrigeration and production of porous foams, degreasing agent	Refrigeration, plastic foam production, metal fabricating	Attack stratospheric zone layer, green house gas
Hydrochloric acid	Combustion of coal or waste containing chlorinated plastic	Coal-fired boilers incinerators	Irritant to eyes and respiratory system
Hydrogen Cyanide	From metal plating blast furnaces, dyestuff work	Metal fabrication primary metals, textiles	Capable of affecting nerve cells
Hydrogen Fluoride	Catalyst in some petroleum refining etching glass, silicate extraction by product in electrolytic production of aluminium	Petroleum, primary metals, aluminium	Strong irritant and corrosive action on all body tissues, damage to citrus plants. Effect on teeth and bones of cattle from eating plant
Ozone	Reaction product of VOC and nitrogen oxides	Not produced directly	Irritant to eyes and respiratory system

Odours	Slaughtering and rendering animals tanning animal hides, canning smoking meats, roasting coffee brewing beer, pro cessing toiletries.	Food processing, allied industries	Objectionable odour
Ketones	Used as a solvent in coasting	Surface coatings, printing	Sensory respiratory irritation
Lead	Incineration, smelting and coasting, transportation	Copper and lead smelting MSWs	Neurological impairments, kidney, liver, and heart damage
Hydrogen sulphide	Refinery gases, crude oil, sulphur recovery, various chemical industries using sulphur compound	Petroleum and chemicals Kraft pulping process	Foul odour of rotten eggs, irritating to eyes and respiratory tract, darkening exterior paint
Nitrogen oxides	High-temperature combustion metal cleaning, fertilizer, explosives, nitric acid, carbon and combustion, manufacturing of H_2SO_4	Metal fabrication, heavily chemicals	Irritating gas affecting lungs, vegetation dam-age

2.3 SOURCES OF AIR POLLUTION

There are two source of air pollution namely

1. Natural air pollution
2. Man-made air pollution

2.3.1 Natural Air Pollution

The sources of natural air pollution are - Atmosphere pollution is caused due to natural causes, source of which are:- PERRY, R.S.& CHILTON C. H. (1973)

a) Micro-organism

b) Smoke gases from forest fires

c) Wind brain dust

d) Gases and odours from swamps and marbles

e) Fog

d) Volcanic and gases

g) Pollen

h) Sea Sal nuclei

2.3.2 Man-Made Sources

The activity of man in making effort to provide things fore his or survival on earth has also initiated sources of air pollution. Those activities that releases man-made air pollution are crushing, grinding, milling, fuel burning, refuse burning, gas flaring, food processing etc

2.4 CLASSIFICATION OF AIR POLLUTION

The variety of matters emitted into the atmosphere by natural and anthropogenic (man-made) sources is so diverse that it is difficult to clarify but it can be categorically divided into two (Smith 1998).

a) Primary pollutants and

b) Secondary pollutants

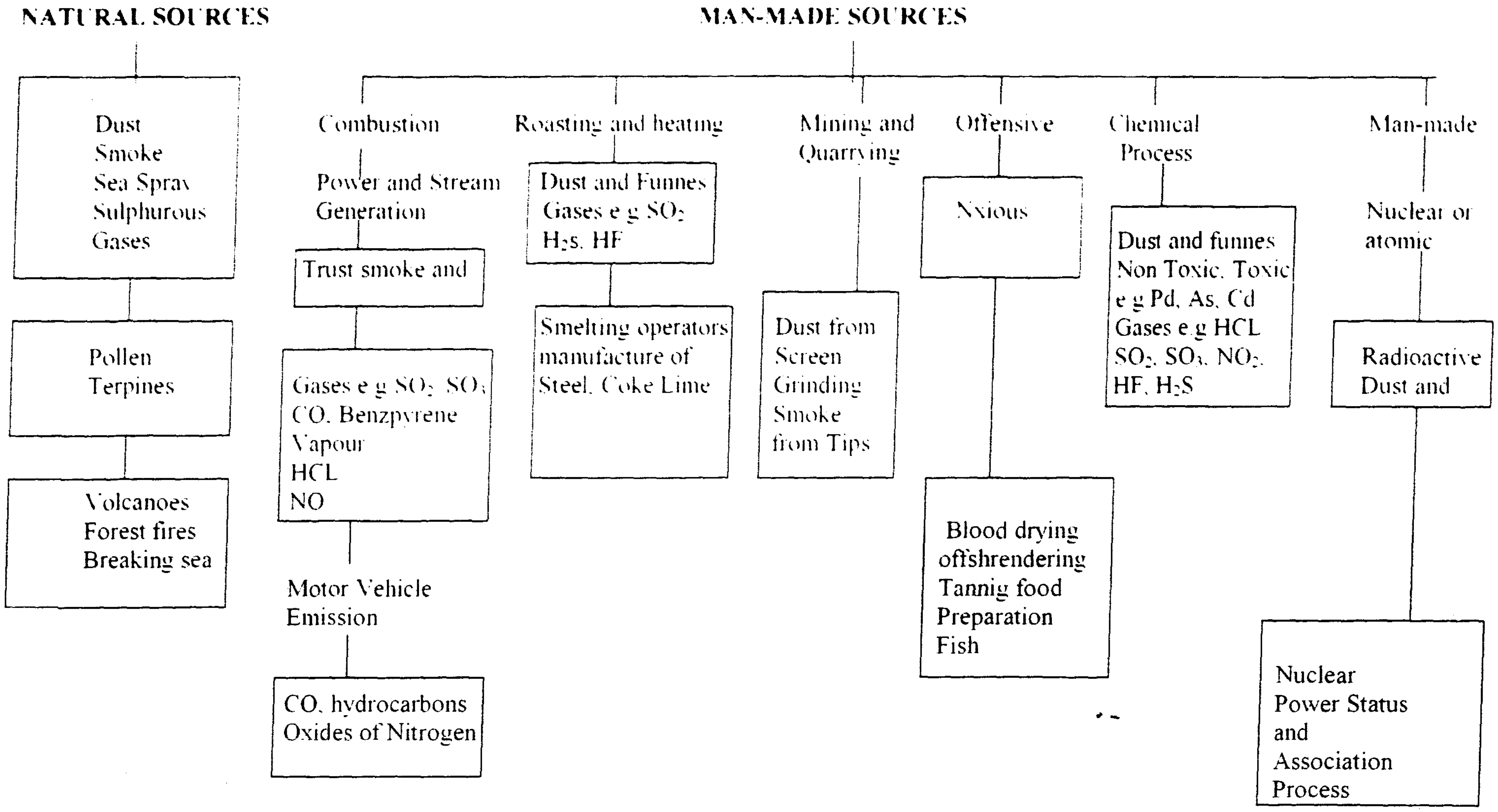
2.4.1 Primary Pollutants

Pollutants that are emitted directly from the sources are called primary pollutants Example of such pollutants are: Inorganic gases such as sulphur dioxide and hydrogen fluoride, olefin and aromatic hydrocarbons, particulate matter such as ash, smoke, dust, fumes, mist and spray, and radio active compounds of the large number of primary pollutants emitted into the atmosphere, only few are present in sufficient concentrations to be of immediate concern. The major types of pollutants are five in number namely: - hydrocarbons, carbon dioxide, sulphur dioxide, particulate matter and nitrogen dioxide (Smith, 1998). Carbon dioxide is generally not considered as an air pollutant but because of its effect in global background concentration and its influence on global climatic pattern is of great concern. Radioactive pollutants are of specialized nature and their impact

2.4.2 Secondary Pollutants

Pollutants that are formed in the atmosphere by chemical interactions among primary pollutants and normal constituents of the atmosphere are called secondary pollutants. Examples of such pollutants are: - Nitrogen dioxide, ozone, aldehyde ketones, and several sulphate and nitrates salt are included in this category. Secondary pollutants are formed from chemical and photochemical reactions in the atmosphere (Smith, 1998). Mechanisms and various steps involved in the process are influenced by many factors such as concentration of reactions, the amount of moisture present in the atmosphere, degree of photo-activation, meteorological forces, and local topography

Fig.1 **The Sources of Air Pollution**



2.5 CLASSIFICATION OF POLLUTION

Pollutants can be classified according to the type of source, i e Natural and anthropogenic (man-made) source, as well as sub-classifications within the earth group There are many types of natural sources and they are briefly described by the following subdivision

2.5.1 Chemical and Metallurgical Industries Sources

The major sources of air pollutants are chemical and metallurgical industries In addition to SO_2 emission, these operations usually produce dust and fumes at primary metal oxides and small quantities of trace metal (Olabanji, 2003). In the case of iron and steel industry, air pollution originates from large scale high temperature processing of coal and iron are The major emission source include are sintering, coke ovens, and waste water quenching of hot coke and furnaces effects Some of the significant emissions are dust, fumes, hydrocarbon, tars, H_2s and SO_2 In non-metallic numeral industries like cement, ceramics, glass and refractors, the operation of mining, crushing, transport and storage of the materials result in the emission of large quantities of hazardous dust The chemical process industries are the sources of a wide variety of air pollutants emission with raw material processing, reaction products and the purification Some of the pollutant emitted from inorganic industries are H_2SO_4, SO_2, NH_3, NO2, hydrogen fluoride, H_2s and HCL gas synthetic organic chemical industries emit a variety of hydrocarbon compounds and solvent like $C_6H_6H_5CH_3$ into the atmosphere (PERRY R. H. & CHILTON 1993)

2.5.2 Food Processing and Agricultural Sources

During presentation of food materials and packaging is a wide range of activities in food processing. These activities release pollutants such as dust from grinding milling and handling operations and odours associated with biological decay of food materials are produce from these activities. Also, the use of agricultural chemicals for improvements in crop yield, for controlling weeds & insects result in emission of pollutants like nitrates and phosphate, pesticides, arsenic and lead particulate into the atmosphere, thereby contaminating the air

2.5.3 Combustion Sources

The source of anthropogenic (man-made) pollution is the product of combustion The combustion of fossil fuels results in the emission of a variety of pollutants into the atmosphere of which the major one are: - CO, No_x, SO_2 and particulate matter, such as soot, fly ash. (Bukola, 2003)

Also, few quantities of water vapour and trace metal oxides e g lead oxides of mercury and cadmium. Incineration of solid combustible wastes and refuses give off a wide variety of pollutants depending upon waste composition and combustion conditions. Examples of these pollutants are - particulate, ammonia, hydro carbons, CO, No_x SO_2. Benzyrene and aldehyde (Perry R H & Chilton C. H., 1993).

2.5.4 Pulp and Paper Industry Sources

These are sources of air pollutants emission into the atmosphere. Combustion of wood waste result in large particulate emission into the atmosphere, sulphur bearing mal-odorous gases such as H_2S, methyl sulphides, and methylmercaptan are emitted from below tanks, evaporators and recovery furnaces.

2.5.5 Petroleum Refining Sources

Petroleum operations are a major source of air pollution, emitting such pollutants as oxides sulphur and sulphur containing vapours from various stage of the refining process, particulate from catalyst regeneration and recycling H_2S and mercaptans which are stripped from lighter grades of fuels and hydrocarbons from lakes in values pipelines and storage tanks (Odedipe, 1997)

2.5.6 Classification of Anthropogenic Air Pollutants Source (George, 2000)

Table: 2.2.

SOURCE TYPE	CATEGORY	IMPORTANT SOURCE	TYPICAL POLLUTANTS
Combustion	Stationary	Power plants, industrial boilers, diesel generators municipal or industrial incineration. Refuse burning	Oxides of sulphur NO_x, CO, smoke, fly ash, trace metal oxides, CO, hydro carbons NO_x, SO_2, particulate

Roasting and Heating Process	Non ferrous metallurgical Ferrous Metallurgical Non-metallurgical	Roasting smelting and refining operation Material handling, are sintering and palletising coke ovens, blast furnace steel furnace Crushed stone processing cement, glass refractors and ceramics manufacture coal clearing	Dust, smoke, metal fumes (Cu, Pb and Zn) oxides of sulphur smoke, fumes, CO, odours H_2S, organic pairs fluorides Mineral and organic Particulate, SO_2, NO_x, dust fumes
Chemical Petroleum Pulp and paper	Petroleum Refining Inorganic chemical Organic chemical	Boilers, process heaters catalysts regenerations flares reaction, storage tanks, compressor engines. Sulphuric acid plant fertilizer manufacture nitric acid and ammonia plants, phosphoric acid manufacture Plastic paints and varnish manufacture, synthetic tuber, rayon, insecticides, soap and detergent manufacture methanol, Phenol etc	Oxide of sulphur hydrocarbons, NO_x particulate matter, CO aldehydes, ammonia odours SO_2, HF, H_2S, NO_x, NH_3, particulate matter, H_3PO_4 etc Particulate matter odours, SO_2, CO, Organic intermediates Product gases and vapour etc

	Pulp and paper Kraft process	Digestive blow system, pulp washers, recovery furnace, evaporators, oxidation towers	Particulate matter odorous sulphur compound (H_2H methylmercarptan, methyl sulphide) and SO_2 (sulphite process)
Food And Agriculture	Food processing	Drying, preserving packaging.	Vapours, odours dust
	Crop spraying and dusting	Pest and weed control	Organic phosphates chlorinated HC, arsenic lead
	Field burning	Refuse burning	smokes fly ash and soot

2.6. EFFECTS OF AIR POLLUTION

The general areas into which effects of air pollution can be classified are (Thomas, 2000) -

1) Harmful effects of air pollution, which include: - effects on health, vegetation and materials

2) Hazardous effects include: - Ozone layer depletion, global warning, acid rain, and green house effect.

2.6.1 Harmful Effect of Air Pollution On Health

2.6.1.1 Sulphur Dioxide

SO_2 has its primary effect on the respiratory tract, producing irritation and increasing airway resistance, it increase mucus secretion also SO_2 has been implicated in several acute accidents of air pollution. During a 5-day period marked by a temperature inversion and a fog in London in December 1952, about 3500-4000 deaths in excess of normal were recorded (Pius, 2001). Autopsies revealed irritation of respiratory tract and high level of SO_2 were suspected as being responsible

SO_2 has been implicated in the increased rates of acute and chronic asthma, bronchitis and emphysema observed in people exposed to sever air pollution. Asthma a severe allergic disorder and bronchitis, attack many people annually emphysema a progressive lung disease ones thought rare is ultimate fatal. Many sulphur compounds are harshly irritating to respiratory passage, causing coughing and choking. Their effects are though to be major cause of the abnormal death tolls that have occurred during smog disasters.

2.6.1.2 Oxides of Nitrogen

Nitrogen oxides reduce the oxygen carrying capacity of the blood. Studied on animals have demonstrated a variety of other toxic effects of nitrogen oxides, principally involving the lungs (James, 1999). Nitrogen oxides is bio chemically relatively inert and not very toxic like Co and NO_2 which attaches itself to the haemoglobin of the blood and reduces the O_2 carrying capacity of the haemoglobin. However in polluted air the concentration of NO is normally too low to produce any noticeable effect on the haemoglobin.

Exposure to HO_2 can be quite harmful and the effects vary with concentration and duration of exposure. For exposure ranging from several minutes to one hour, a level of 50-100ppm NO_2 causes inflammation of lung tissue for a period of six-eight weeks after which time the subject normally records (George, 2000). Exposure problem, which is fatal within 3-5 weeks after exposure Death normally results from 2-10 days after exposure to 500ppm or more of NO_2 No, (Oxide of Nitrogen) is known to cause fading of dyes in some textiles.

2.6.1.3 Hydrocarbon and Photochemical Oxidants.

The hydrocarbons are divers, lot and among other things are almost certainly involved in raising cancer death rates. At the concentration usually found in urban air, the hydrocarbons cause no adverse effect on human health. Aliphatic hydrocarbons produce undesirable effect only at concentration 10_2 to 10_3 times higher than those usually found in the atmosphere (William, 1990) No effect has been observed for below 500ppm Aromatic hydrocarbons are more reactive than Aliphatic ones and cause irritation of the mucus membranes The major oxidant produced in photochemical smog is Ozone, contrary to the popular belief, ozone appears to have no effect on the eyes at usual urban concentration. The respiratory systems however may respond to a very low concentration Many oxidants are produce in photochemical smog. Particular are the peroxyaclonitrate (PAN), causes eye irritation, oxidants such as PAN and Peroxybenzoly nitrate (PBN), irritates the nose and throat, and cause chest constriction, which aggravates asthma (Azeez, 2001)

2.6.1.4 Carbon Monoxide (CO)

Carbon monoxide has no odour or colour. The result is that one can breath it in for long periods without knowing it. If the concentration is high enough and exposure time is fairly long the victim can die without realizing, what was happening. That is why CO is called the silent killer

Carbon monoxide is dangerous to man because of the strong bond it forms with the Iron in haemoglobin. By forming very stable complex with haemoglobin (HB) in the red blood cells, carbon monoxide displaces oxygen and prevents the latter from being carried through the blood stream (Meethan, 1981). The life of a person suspected of having carbon monoxide poisoning could be saved, if reasonable amount of pure oxygen can be administered to the patient This is so, because the reaction of CO with haemoglobin is reversible and administration of pure oxygen can replace the carbon monoxide with oxygen and haemoglobin. Higher carbon monoxide can cause impairment of central nervous system, changes in heart and pulmonary functions, drowsiness coma, respiratory failure and eventually death occurred (Colvile, 1999)

2.6.1.5 Particulates

Particulates may be defined as solid or liquid matter whose effective diameter is larger than a molecule but smaller than approximately 100gm. Particulates dispersed in a gaseous medium are collectively termed an Aerosol. The terms smoke, fog, haze and dust are commonly used to described particular types of aerosols, depending on the size, shape and characteristics, behaviour of the dispersed particles. Particulates may cause physical damage of certain materials. Particulates whipped by the wind grind exposed a materials by abrasive action, particles settling in electronic equipment can cause breakdown in resistance and foul contacts and switches (George, 2000)

Physical without or more of the clearance mechanism, in the respiratory tract of man and animals (inhibiting the ciliary transport of mucus, for example) People who have asthma know that, heavy concentration of particles in the air increases discomfort. In extremely polluted regions these diseases often lead to death. Particulates may also injure human beings or animals because they are inherently essentially toxic. Lead compounds are emitted in automobile exhaust and fertilizer factories have caused weakening of bones and loss of mobility in animals, which have extended plants covered by the dust.

2.6.2 Effects of Air Pollution On Vegetation

The effects of air pollution on vegetation can result to death, stunted growth, causes crops to be bleached, discoloured and reduces crop yield (Onoma, 2001). Example of colour damages, such as the silvering of vegetable leaves by oxidants, however, the consumer will not purchase such vegetables on aesthetic grounds, so the grower still sustain a loss. Examples of such air pollutants are:- sulphur dioxide (SO_2), ethylene and hydrogen fluoride (HF).

2.6.3 Effects of Air Pollution on Materials

These include the mechanism of deterioration resulting from contact of pollutants with objects examples are: - Acid aerosol ruin nylon nose, hydrogen sulphide tarnished silver, smoke dirties laundry. Ozone is photochemical smog cracks rubber, weaker fabrics and fades dyes other important effects are as follows:- Impairment of visibility, the soiling of goods, discolouration and corrosion etc(Pius,2001).

1) Impairment of Visibility: - the scattering of sunlight causes a polluted atmosphere by particles

suspended in the air, which decreases visual range Reduction in visibility creates a lot of problems, the most significant are: - Highway, harbour operation and air craft Reduced visibility can also cause adverse aesthetic impression which can seriously restricts growth and development of any place.

2) Discolouration: - Air pollutants causes discolouration on buildings, example is the soot which blacker building, but can accumulate and become uncrushed The can be hide line and decolouration and thereby disfigure and reduces their aesthetic appeal Another common effect is the discolouration of plant by certain gases An example is the darkening of white point with a lead base by hydrogen sulphide

3) Corrosion: - Great economic importance of corrosion is the corrosion action of acid gases on building materials, such gases can cause stone surfaces to blister and peel, mortar can be reduced to powder. Materials are also damaged by the corrosion action of some pollutants Another common effects are the deterioration of tyres and other rubber good, cracking and apparent "during" occur when these goods are exposed to ozone and other oxidants

2.6.4 Hazardous Effects of Air Pollution in the Globe

The main global hazardous effects of air pollution are - Ozone depletion, acid rain, green house effects, toxic air pollutants, radiations, haze and visibility and global warming

2.6.4.1 Ozone Layer Depletion

A protective ozone layer is located in the stratosphere about 22 miles above the earth's surface. This layer protects us from the sun's harmful ultraviolet radiation Thus chemicals such as CFC's are damaging protective shields, halons, and methylchoroform and can lead to harmful health effects such as skin cancer and cataracts However, this layer may be depleted by reactions which reach the atmosphere, of particular concern are the water vapour and nitrogen oxides released by high altitude, air crafts nitrous oxide produced by the action of bacteria in soils (amount of which have become significant with the large scale use of nitrate fertilizers and chlorofluoro-hydrocarbons which are widely used as a spray propellants and refrigerants It is postulated that, the combine effect of aircraft engine effects, nitrate fertilizers and halogens would cause considerable depletion of the ozone layer and cloud result in an increase in ultraviolet radiation reaching the earth (Agada, 2000)

2.6.4.2 Acid Rain

"Acid Rain" is a broad term describing acid rain, snow, fog, and particles. It is caused by sulphur dioxide and nitrogen oxides released by power plants, vehicles, and other sources. Acid rain harms plant, animals and fish, and erode building surfaces and national monuments. In addition, acidic particles can hurt people's lungs and reduces how far we can see through the air. An example is the industrial region of U.S.A has significantly lower pH than that of else where in the country. There are some speculation that tail smoke stacks and long-range transport of sulphur (up to 1000km) making the acid rain problem a regional one (Olabanji, 2003). This has been collaborated into -

1) Increase in global average temperature. - It now appears that the world is warming at twice the rate protected just five years ago. Scientist believed that by the year 2030, global average temperature would be between 3 and 8 degree Fahrenheit higher than it was averaged between 1950 and for the past two million years (Olabanji, 2003).

2) Change in regional rain patterns. - The evaporation or transportation cycle at the global level is expected to speed up. This means that it would rain more, but the rain will evaporated faster leaving soil diver during critical parts of the growing season. The harsh weather conditions mentioned above has worsened by the absence of rains which could have provided the required "cooling effect" for city dwellers, farmers etc whose business thrives in the rainy season (Adedipe, 1997).

2.6.4.3 Green House Effect

The earth must shed energy space at the same rate at which it arrives in the form of short-wave length radiation. Some of this radiation is reflected away by the earth's surface and atmosphere. Most of it however, passes straight through the atmosphere to warm the earth's surface. The earth gets red of this energy (send it back into space) in the form of long-wave length, infrared radiation. The green house effect occurs because there is an atmosphere above the earth's surface. That atmosphere, when it is clear, in largely transparent to solar radiation, but it is largely opaque to long wave radiation emitted by the surface. Anybody in space emits radiation, the wavelength of this radiation is inversely related to the body (Shaba, 2003). The main green house gases are water vapour, carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCS) and hydrogenated chlorofluorocarbons (HCFCS), Ozone (O_3) and nitrous oxide (N_2O) (Agada, 2000)

2.6.4.4 Global Warming

Global warming refers to an average increase in the earth's temperature, which in turn causes changes in climate. Rising global temperatures are expected to raise sea level, and change precipitation and other local climate conditions. Changing regional climate could alter forests, crop yields and water supply; it could also threaten human health, and harm birds, fish, and many types of eco-system.

Global warming is a popular term used today to described the increase in temp of the earth's surface due to emission of CO_2, and other green house gases into the atmosphere, there is concern that human activities may be in advertently changing the climate of the globe (Olabanji, 2003)

2.6.4.5 Radiations

Radiation occurs naturally (e.g. radon) but we also use radioactive to generate electricity and to diagnose and treat medical problems. Frequent exposures to radiation can cause cancer and other adverse health effects, including genetic defects in the children of exposed parents or mental radiation in the children of mothers exposed during pregnancy. International agreement have banned most testing of nuclear weapons in the atmosphere and have help eliminate the large source of radiation But the number of electronic devices that produce small amount of radiation is steadily increasing These devices include lasers, X-ray machines, colour television sets and microwave ovens Scientist Are trying to determine the effects of frequent exposure to small amount of radiation can have on people. Radiation originates in the nuclei radiation includes: -alpha radiation beta radiation, gamma radiation and x-rays (John, 2003).

2.7 AIR POLLUTION CONTROL

The control of air pollution is of utmost concern, if the ambient air quality standards tolerable to humans, animals and vegetation are to be maintained. It is difficult to stop air pollution completely, instead, practical measure are to be taken to reduce the effect This measures had to be taken to ensure that pollutants emission do not exceed ambient the standard of air Control measure of some air pollutants such as Sulphur dioxide, Carbon monoxide, Hydrocarbons, Particulates, and Nitrogen oxide (George, 2000).

2.7.1 Control of Sulphur Dioxide

There are different ways of or steps that are used in removal of sulphur from fuels before combustion and from stack gas after combustion since coal is the principal source of SO_2 pollution. one method involves the removal of sulphur from coal before burning it The other more important methods are used to remove sulphur dioxide (SO_2) from stack gas, and are divided into two namely - The recovery system and throwing system. Some of these systems are dry while others are wet and involve scrubbing with a water solution. A dry throw away system which has been used with only limited success involves the injection of dry limestone or dolomite into the boiler followed by recovery of dry line, sulphites and sulphates. As shown in the reaction below (John, 2000)

$CaCO_3 + MgCO_3 + SO_2 + \frac{1}{2} O_2 \longrightarrow CaSO_4 + MgO + 2CO_2$ The solid $Caso_4$ and Mgo are removed electrostatic precipitators or cyclone separators

The most commonly used wet throw away system is the wet limestone process, which limestone is inject into the boiler and removed along with sulphur containing salts in a wet scrubber This process is an efficient means of reducing SO_2 emission and additional advantage of very effective particle removal.

2.7.2 Control of Carbon Monoxides

The main sours of CO are the automobiles (internal combustion engines) motor vehicles. Both thermal and catalytic exhaust system reactors were designed to change carbon monoxide to carbon dioxide. The most practical method of reducing the CO emission from stationary combustion source is by proper design, installation, operation, and maintenance of the combustion equipment

The main problem with the thermal reactor is the lack of an economic heat-and-corrosion resistant material to use in the chamber construction. While in the case of the catalytic converted the problem is lack of durable catalytic, which cannot be easily deactivated or poisoned by the waste gases.

2.7.3 Control of Hydrocarbons

The incineration, adsorption, absorption and condensation processes are techniques used to control hydrocarbon emission from their sources. The polluted gas stream is passed through one or several absorbers operated parallel. The absorbers are generally operated within the temperature range of 30°C and 60°C. The preferred absorbent is granular activated carbon with a mean diameter of 2mm to 4mm. The absorbed vapours are usually removed by passing steam through the system The mixture of steam and hydrocarbon is liquefied in a condenser and cooled down to ambient temperature in a cooler. The hydrocarbons are separated from the water and recovered fro further use Absorption units are fairly expensive in terms of capital cost need little in the way of maintenance or operational manpower.

2.7.4 Control of Particulates

Particulates may be defined as solid or liquid matter whose effective diameter is larger than a molecule but smaller than approximately 100mm. The classification of various particulates may be as follows; Smoke, Soot, Dust, Fumes, Must, Fly ash, Aerosol etc

One of the most prominent sources that contribute to emission of particulate into the atmosphere is the incineration of refuse. And burning of this refuse instead of the normal burning can stop this. And the other sources can be controlled by adherence to FEPA limits on emission of particulates into the atmosphere.

2.7.5 Control of Nitrogen Oxides

The atmosphere nitrogen in the combustion air and bound nitrogen in the fuel itself are two sources of nitrogen, which are contributed to the formation of nitrogen oxides during combustion He formation of these gases is favoured by high temperature and excess oxygen concentration Reduction of flame temperature to prevent NO_x formation is accomplished by the following methods. The use of low excess-air combustion, the circulation of coal fuel gas, the use of the two stage process, injection of water and steam into the combustion zone, Re-designing of the furnace so as to induce tangential and horizontal firing into the combustion chamber.

2.8 AIR POLLUTION CONTROL EQUIPMENT

The equipment used to control emission of pollutants from industrial and domestic sources are as follows:- for particulate emission are gravity settlers (often referred to as setting chambers), mechanical collectors (cyclones), electrostatic precipitators (ESPs), scrubbers (venturi scrubbers) and Fabric filters (Baghouses). Techniques used to control gaseous emission are absorption, absorption, combustion and condensation.

2.9. MODELLING AND SIMULATION

Mathematical modelling and computer simulation are gearing speed application in Chemical Engineering. Mathematical modelling is an explicit technique for representing real world phenomena in terms of mathematical equators. Model is a simplified representation of a system intended to enhance our ability to understand, explain, change, preserve product and possible control the behaviour of a system (Naelamkavil, 1987). Mathematical model of a system only represent the mathematical aspect of a process or system of interest. It gives the description of the process, both the physical and chemical phenomena taking place there in. A model retain the physical properties of the system, it is therefore aimed at providing the simplest possible description of a system which is an exact scaled down replica to the prototype and at the same time retain it physical characteristic (William, 1990). The principle of model formation involved are - Basis, Assignment, Mathematical consistency of the model, solution of the model equation and verification.

SIMULATION: Martin Shubik defines simulation of a system as the operation of a model, which is a representation of the system, the model being amenable to manipulation, which would be impossible, too expensive or impracticable to perform on the system it portrays. Simulation is used for two principal reasons: -

1) To give greater understanding and insight into the behaviour of the physical system and principle up which its design is based.

2) To prove a convenient, inexpensive and time saving of gaining this understanding and insight under a variety of operation condition. The routine and logical steeps of simulation are as follows - Data collection, Problem analysis, Simulation model specification, Model programming, Model verification, Simulation experimentation, Evaluation and Interpretation of simulation result (William, 1990).

CHAPTER THREE

3.0 EXPERIMENTAL METHODOLOGY

The experimental methodology used for these researches is specifically employed to determine the concentration of air pollution in Niger-Delta Area (Calabar). In this research, collected data of already preformed experiments and the mythology of experiments were presented accordingly. The data collected are for the following elements temperature, relative humidity, pressure and wind-speed, which are collected and recorded by means of instruments and the procedures is describe below. The methodological station in the Niger-Delta Area (Calabar) performed this experiment. Such stations include, Climatological stations. Synoptic stations. Agricultural stations and rainfall stations. Most of the data used for this research were collected from the Niger-Delta Area (Calabar). These data are the most recent ones in many years.

3.1 WEATHER OBSERVATION, ANALYSIS AND FORECASTING

Weather stations are locations where weather elements are being measure or observed. There are four types of weather stations recognised depending o the number of weather elements measures, the frequency of measurement, and the status of the observer (Unoma, 2001).

3.1.1 Types Of Weather Stations

3.1.1.1 Climatological Station:

These are stations manned part-time observers making only once or twice daily instrumental observation of temperature, humidity, rainfall, pressure and wind.

3.1.1.2 Rainfall Stations:

These are stations manned by part-time observers who take readings of rainfall only

3.1.1.3 Agricultural Station:

These are stations manned by part-time observers at least twice daily. Instrumental observation of the major weather elements. Evaporation, grass and soil temperatures, and solar radiation are also usually measured in view of their obvious importance in agriculture

3.1.1.4 Synoptic Station:

These are stations manned by full-time professional observers who maintain continuous weather watch and make hourly instrumental observations of the weather On which information is required for the compilation of the synoptic charts and weather maps used in weather forecasting

3.2 THE DETERMINATION OF TEMPERATURE

Temperature is a very important element of and weather, the instrument used for measurement of the temperature is the "mercury in-glass" thermometer, which is a narrow glass tube filled with mercury or alcohol. Maximum and minimum temperatures are measured by the maximum and minimum. The maximum thermometer records the highest temperature reached during the day. The mercury in the close glass tube expands when the temperature rises Its pushes a mental indicator up the tube and this stays at the maximum level when the temperature drops. the end of the indicator nearest the mercury gives the reading of the maximum temperature, to reset the mercury for the next day's reading, the indicator is drawn back by a magnet The, maximum thermometer is used to record the lowest temperature reached during or early in the probably occurs in the middle of the night or early in the morning. The glass tube is filled with alcohol, which allows the indicator to slide freely along the tube. When the temperature drops, the alcohol contracts and drops the indicator towards the bulb by the surface, tension of the indicator. When the temperature rises, the alcohol flows past the indicator leaving it where it was. The end of the indicator farthest from the bulb gives the reading of the minimum temperature and the thermometer is then reset by a magnet for the next 24 hours reading. The mean daily temperature is the average of maximum and minimum Then the mean monthly temperature is calculated and recorded.

3.3 DETERMINATION 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. Then relative humidity of the Calabar metropolis is measured using the hygrometer. These instruments consist of wet and dry – bulb thermometers placed side by side in the Stevenson screen. The wet bulb is kept wet a wick that dips into a reservoir of distilled water. When the air is not saturated evaporation, which produces a cooling, takes place from the most wick. The wet-bulb therefore always shows a lower reaching than the dry-bulb From the easurement, a large difference indicates a low relative humidity and a small difference a high lative humidity. But if both have the same reading, it shows that relative humidity is 100 percent; e air is saturated.

.4 DETERMINATION OF PRESSURE

Air is a mixture of many gases and has weight. It therefore exerts a pressure on the earth's urface, which varies from place to place and time to time. Pressure is being measured using a arometer; variations in the atmospheric pressure on the mercury surface are balanced by the column f mercury surface in the glass tube. This gives the pressure of the air and is read off quickly from en scale on the glass tube. Mercury is used here because it is the heaviest liquid known If the ressure increases, the air pressing on the surface. will force up the mercury column to increase and n this case a high pressure is measured. When the pressure decreases. as less air presses on the urface, the mercury colour will drop, and a low pressure is measured.

.5 DETERMINATION OF WIND SPEED

Wind is air in motion and gas both direction and speed. The wind speed is measured using an nemometer, this instrument consist of three or four semi-circular cups attached to the ends of orizontal spokes mounted on a high vertical spindle which makes it easy for measuring the wind speed. As the concave sides of the cups offer greater resistance to the winds, the horizontal spokes will rotate; and a control rod is moved which transmits the velocity (speed) of the wind in kilometres per hour to an electrically operated dial. Mostly the speed recorded is not absolutely accurate because after the wind has abated, the rotation continues due to its own momentum.

CHAPTER FOUR

4.0 CONCEPTUALISATION F MODELING TECHNIQUE.

4.1 Analysis of Numerical Atmospheric Models

Modern weather forecasting at the National Meteorological Centre (NMC) involves the use of thermodynamic equations. These time-dependent equations are programmed into computer to predict the future state of the atmosphere. These equations involve the temperature, pressure and the total water content of the atmosphere. The numerical techniques based on these model equations used at National Meteorological Centre were implemented operationally in June 1966(Unoma, 2001)

Pollutants are transported through the atmosphere by wind contents from their point of release to downwind receptors. They are dispersed and diluted so that an emission, toxic at its release point, may be harmless at ground level downwind. The higher the release point above the surroundings the more buoyant is the plume, the greater is the dilution The major meteorological stability and wind velocity. Atmospheric stability is affected by solar radiation and the vertical temperature gradient of the atmosphere called lapse rate. Best conditions for dispersion are high wind and a highly unstable temperature gradient (Super adiabatic). As the atmosphere becomes progressively more stable, wind speeds tend to decrease and plume dispersion becomes progressively poor. An indication of atmospheric stability can be gained from smoke plume behaviour (Paul, 2000)

Increasing wind speed aids dispersion. The plume blown over more rapidly and rises less in the atmosphere. Because of this, higher ground concentrations may be experienced closer to the stack, but dilution occurs, concentration for the downwind will be reduced

4.2 Assumptions for the Model

The following assumptions were made in order to simplify the model-imposed limitations and make the process, obtaining solutions and the predictive nature of the model more accurate.

1. Vertical and crosswind diffusion occur according to Gaussian distribution
2. The emission rate, Q is continuous and constant.
3. The horizontal wind velocity and the mean wind direction are constant
4. The pollutant concentration at any point in space (X, Y, Z).

5. 1 mole of any gas at constant temperature and pressure, occupy the same or equal volume, i e the stack gases will occupy the same volume in the industrial area
6. Wind speed taken is non-uniform in space but is equal to the prevailing value at the point of measurement.
7. The atmospheric temperature at nay given moment is equal to the prevailing one
8. There is no upper barrier to vertical diffusion and there is no crosswind diffusion barrel
9. Emission reflected up ward from the ground are distributed vertically as if release from an imaginary plume being the ground and are additive to the actual plume distribution

4.3 PARAMETERS FOR THE MODEL.

When gaseous and particulate pollutants are emitted from various sources into the atmosphere The following interactions occur;

1. Transport and mixing by wind.
2. Dilution with a resultant decrease in concentration.
3. Chemical reaction between pollutants while in transport is assumed to be negligible and limited to physical properties.

Certain parameters and variables must be considered in order to have a perfect model Parameters that would be considered in the development of the air quality model include wind speed, temperature, relative humidity, density, dispersion coefficients and pressure

4.3.1 TOTAL PRESSURE

The total pressure of a mixture of ideal gases according to Dalton's law is the sum of the individual partial pressures of constituent gases. For this study, air is considered as a mixture of the basic components of pure dry air (oxygen, nitrogen etc), vapour pressure and the pollutants The total atmospheric pressure obtained from the weather station is shown below.

$P(atm) = P(ppa) + P(pollutants)$

Where:

P(atm) is total atmospheric pressure

P(ppa) is the total partial pressure due to the components of pure dry air

P(pollutant) is the partial pressure due to pollutants

4.3.2 Wind And Dispersion

When pollutants are emitted into the atmosphere, the pollutants are transported away from the source The transportation and diffusion depends on the wind speed and direction The wind speed influences the rate at which the pollutant molecules travel and consequently the dilution rate The wind speed and direction determines the area into which the pollutants are carried and the intensity of mechanical turbulence produced as the wind flows over and around the surface objects, for example three and buildings. Thermal turbulence and associated intense mixing develop as a result of temperature difference in different layer of air (McGraw Hill Encyclopaedia)

4.3.4 Atmospheric Temperature Relative to Humidity.

From literature, a relationship linking temperature, vapour pressure and relative humidity is obtained by

Chigbua (1997).

$$P = HPs \text{ -----------------------------------} 1$$

Where:

P = vapour pressure

Ps = saturated vapour pressure

H = relative humidity.

Ps is given by

$$Ps = 6.1x10^{-4} \exp\left(\frac{19.7t}{t+273}\right) \text{ -----------------------------------} 2$$

Ps = mbar

T = temperature in K

t = temperature in °C

By substituting equation 2 into 1, we obtain:

$$P = 6.1x10^{-4} H \exp\left(\frac{19.7t}{t+273}\right) \text{---------------------------------}3$$

Taking ln of both sides of the equation above gives:

$$\ln P = 6.1x10^{-4} H \exp\left(\frac{19.7t}{T}\right) \text{---------------------------------}4$$

Where t = T – 273

$$\ln P = 6.1x10^{-4} H \exp\left(\frac{19.7[T-273]}{T}\right)$$

$$T = \frac{3.99x10^{2} H}{0.012H - \ln P} \text{-------------------------------------}5$$

4.3.3 Density

In analysis the atmosphere, it is more convenient to use density rather than volume

Density = P = mass/volume

$$\therefore \rho = {}^{m}\!/_{v} \text{---}6$$

$$\Rightarrow m = \rho v \text{---}7$$

from the relation v = n/c ------------------------------------8

substituting equation (8) into (7) gives

$$m = {}^{\rho n}\!/_{c} \text{---}9$$

Where:

n = number of moles = 1 (unit moles)

C = Co = Cpollutants = initial pollutants' concentration.

Equation (9) therefore becomes:

$$m = {}^{\rho}\!/_{Co} \text{---}10$$

4.4 Development of the Model Equation

The "Gaussian distribution" developed by Guass et al is expressed as :

$$\frac{ni}{\lambda} = (\eta_m/\lambda)\, e^{-(Xi - Xi)2/2\delta^2}$$

Where:

Xm = mean arithmetic average value of the class characteristic amongst the total population

$$= \sum\left({niXi}/{N(d)} \right) \ldots\ldots 11$$

Xi – Xm = mean arithmetic average value of the class characteristics between members of subclass i and the mean subclass m.

δ = The standard deviation of the root mean square deviation from Xm

$$= \sqrt{\frac{\sum\left[ni(Xi - Xm)^2\right]}{\lambda^2(N-1)}}$$

Dealing with only intervals of 1 units of dimension a per interval equation (11) becomes

$$ni = (nm)\, e^{-(Xi - Xi)2/2\delta^2} \ldots\ldots 12$$

Where:

$Xm = \sum(niXi)/N$ in units of d and

$$\delta = \sqrt{\frac{\sum\left[ni(Xi - Xm)^2\right]}{(N-1)}} \quad \text{in units of d}$$

On integrating equation(12), setting Xi – Xm = U.

We have:

$$N = \sum_{-\infty}^{\infty}(ni\Delta\mu) = \int_{-\infty}^{\infty} ni\,du = \int_{-\infty}^{\infty} nm\, e^{-u2/2\delta^2}\, du. \text{ We get:}$$

$$N = n_m\delta\,(2\pi)^{1/2} \ldots\ldots 13$$

On dividing equation (12) by (13), we obtain:

$$\frac{ni}{N} = \frac{e^{-(Xi - Xm)^2/2\delta^2}}{\delta\,(2\pi)^{1/2}} \ldots\ldots 14$$

Rearranging equation (14) above in the form widely used to develop stack gas dispersion models based upon the Gaussian distribution:

$$ni = \frac{Ne^{-(Xi-Xm)^2/2\delta^2}}{\delta(2\pi)^{1/2}} \quad \text{-------------------------15}$$

Neglecting the crosswind diffusion of the plume i.e without regard to any diffusion in the y direction. Applying the Guassion distribution equation, equation (15) becomes:

$$ni(X,Z) = \frac{Ne^{-(Zr-Zm)^2/2\delta^2}}{\delta z(2\pi)^{1/2}} \quad \text{------------------16}$$

Where:

N = Total grams of emissions in the entire 1m thick disc

Zr = any receptor location:

Zm = location of the mean emission density

δz = Vertical standard deviation of the emission densities in M(since λ 1m/interval)

Ni is a subpart of N distributed in the vertical interval

$n_i(X,Z)$ is the integrated cross ional emission density seen at the receptor Zr, when viewing the X – Z Plane.

Thus he Gaussion distribution in the Z- dimension, including upward reflection from the ground becomes:

$$n_i(X,Z) = \frac{Ne^{-(Zr-Zm)^2/2\delta^2}}{\delta z(2\pi)^{1/2}} + \frac{Ne^{-(Zr-Zm)^2/2\delta^2}}{\delta z(2\pi)^{1/2}}$$

By making the following substitutions into the equation above

N = 0

Zr – Zm = Hr – He

Zr – Zm = Hr – (-He)

= Hr + He.

Where:

He = height of plane centerline above ground, M

Hr = height of receptor above ground, M.

We then obtain:

$$n_i(X,Z) = \frac{\dot{i}\;a}{u\delta z(2\pi)^{1/2}}\left[e^{(Hr-He)^2/2\delta^2 z} + e^{-(Hr+He)^2/2\delta^2 z}\right] \text{-------------}18$$

By including the crosswind Gaussian distribution of $n_i(X,Z)$ in the y-dimension:

$$n_i(X,Y,Z) = \frac{n_i(X,Z)e^{-(y-ym)^2/2\delta^2 y}}{\delta y(2\pi)^{1/2}} \text{------------------------------}19$$

Since there is no diffusion barrier in the crosswind dimension, no need for another reflection term in the equation above;

By making the substitutions below into equation (19)

C = $n_i(X,Y,Z)$

Zr = Hr

$n_i(X,Z)$ = the right hand side of equation (19)

y_m = 0, for the location of the mean emission density at the plane centerline in the cross wind or y – dimension.

Y = distance from the receptor to the plume centerline in the crosswind or y-dimension, the well know generalized Gaussian dispersion equation for a continuous point - source plume is obtained.

$$C = \frac{Q}{u\delta z\delta y(2\pi)^{1/2}}e^{-y^2/2\delta^2 y}\left[e^{-(Zr-He)^2/2\delta^2 z} + e^{-(Zr+He)^2/2\delta^2 z}\right] \text{-------}20$$

Where:

C = concentration of emissions g/m^2 at any receptor located at

X = meters downwind.

Y = meters crosswind from the centerline

Zr = meters above the ground.

Q = source emission rate g/sec.

U = horizontal wind velocity m/sec.

He = plume centerline height above ground, M.

δz = vertical standard deviation of the emission distribution. M

From the generalize Guassion dispersion equation obtained above, we obtain the basic Guassian puff formular:

$$\Delta c = \frac{\Delta m}{2\pi \delta y^2 \delta z} \exp\left[\frac{-1}{2}\left(\frac{Xp - Xr}{\delta y}\right)^2\right] \exp\left[\frac{-1}{2}\left(\frac{Yp - Yr}{\delta y}\right)^2\right] \exp\left[\frac{-1}{2}\left(\frac{Zp - Zr}{\delta z}\right)^2\right]$$

----------------------------21

If at time t, the center of a puff is located at P(t) = (Xp, Yp, Zp), then the concentration due to that puff at the receptor r = (Xr, Yr, Zr) can be computed from the above equation

By substituting ΔM from equation (10) into the equation above, we obtain

$$\Delta c = \frac{\rho}{2\pi \delta y^2 \delta z co} \exp\left[\frac{-1}{2}\left(\frac{Xp - Xr}{\delta y}\right)^2\right] \exp\left[\frac{-1}{2}\left(\frac{Yp - Yr}{\delta y}\right)^2\right] \exp\left[\frac{-1}{2}\left(\frac{Zp - Zr}{\delta z}\right)^2\right]$$

----------------------------22

From the relation: Δc = Co – C --23

We have C = Co - Δc ---24

Co, from the above equation can be obtained thus:

Junge (1972) stated that the concentration of a specific pollutant changes with time

$$\frac{dcl}{dt} = \text{turbulent diffusion} + \text{advection} + \text{emission} + \text{sink} + \text{reactivity rate}$$

or

$$\frac{dcl}{dt} = \text{mixing and transport} + \text{input} - \text{output and reactions}$$

dt (physical rate) (biological and chemical rates)
physical removal processes

The rate of transfer as a function of concentration gradient is represented by the basic mathematical expression.

$$\frac{\delta r}{\delta\theta} = \frac{\delta\delta^{2}\Gamma}{\delta x^{2}} \quad \text{--}25$$

Where:

Γ = concentration of the property to be transferred

θ = time

X = distance measured in direction of transport

δ = proportionality constant for a system. For real gases and liquids, δ, the proportionality constant for mass transport is the diffusivity, here and is given by (Foust et al. 1980).

$$\frac{N_{A}}{Ar} = \frac{\wp dcA}{dx} \quad \text{--}26$$

Where:

N_A/A = The net flux at steady state

N_A = rate of mass transport, kmol/hr

A = the area within which mass transport occurs, m^2,

$\wp$ = mass diffusivity m^2/hr,

C_A = concentration of pollutants

For a binary mixture, if a gradient exists in A(gas), there also exists an opposite gradient in gas B (air). Equation (26) may be derived for gas B,

$$\frac{N_{B}}{Ar} = \frac{-\wp dcB}{dx} \quad \text{--}27$$

The total concentration of gas mixture a and b is given by:

$$C_T = C_A + C_B \quad \text{--}28$$

With the assumption that the gases in consideration (air and pollutants) follow perfect gas law, it can be shown that (Hirschfielder et al, 1954)

$$\wp = \frac{1}{6} l \bar{c}$$ --29

Where:

$$\bar{C} = \left(\frac{8RT}{M\pi}\right)^{1/2}$$ ---30

C = arithmetic mean speed, cm/sec.

R = gas constant, 8.314 x 10^7 erg/kgmole

T = molecular weight, g/gmole

L = free mean path, cm.

But l = $$\frac{R^1 T}{\left(\frac{1}{3} + \frac{2^{\sqrt{2}}}{3}\right) \bar{A}^{\rho\pi\delta^2}} = \frac{R^1 T}{7.67 x 10^{23} \rho\pi\delta^2}$$ ----------31

Where :

$\bar{A}$ = Avogadro's number, 6.02 x 10^{23} molecules/gmole.

P = pressure, atm,

R = gas constant, 82.06 atm cm/kgmole

T = absolute temperature, k,

δ = molecular diameter, cm

Equation(4.3.1) can be rewritten as :

$$l = \frac{RT}{7.75\,x10^{29}\,P\,\pi\delta^{2}} \text{ -- } 32$$

Combining equations 32, 31 and 30 gives.

$$\wp = \frac{8.28x10^{-20}\,T^{3/2}}{P\delta^{2}M^{1/2}} \text{ -- } 33$$

For calculation of mass diffusivity, the following equations has been dissolved for binary mixtures (Foust et al, 1980).

$$\wp ab = \frac{2.628x10^{-19}\sqrt{T^{3}\,{}^{1}{}_{2}\left(\frac{1}{MA}+\frac{1}{MB}\right)}}{P\delta AB^{2}\Omega_{2}} \text{ -- } 34$$

Where, $\wp$ ab = mass diffusivity, cm^2/sec

M_A = molecular weight of specific A.

M_B = molecular weight of specific B

P = total pressure, atm,

$\wp$ ab, Ω_2 = Lennard – Jones constants.

For mass diffusivity of many gases developed by Gilliland, 1934.

$$\wp = \frac{0.0043\sqrt{T^{3}\left(\frac{1}{MA}+\frac{1}{MB}\right)}}{P\left(VA^{1/3}+VB^{1/3}\right)^{2}} \text{ -- } 35$$

Where:

V = molar volume.

The Gilliland correlation is used only when the Lennerd – Jones model cannot be used.

For this work since the volume of the pollutants molecules cannot be determined, the modified Gilliland (Hesketh, 1979) will be used. It is given as.

$$\wp ab = 1.299x10^{-6} T^{1/2} \frac{MA}{\rho_A}\left[\frac{1}{MA}+\frac{1}{MA}\right]^{1/2} \text{--36}$$

Where:

T = absolute temperature, K

M = Molecular weight,

The ratio MA/ ρA in equation (36) can be replaced by RT/ ρ_t by the use of ideal gas law where R is the universal gas constant and PA, the total pressure of component A

Therefore equation (36) can be written as :

$$\wp ab = 1.299x10^{-6} T^{1/2} \frac{RT}{\rho_A}\left[\frac{1}{MA+MB}\right]^{1/2} \text{--37}$$

$$\wp ab = 1.0659x10^{-4} \frac{T^{3/2}}{\rho_A}\left[\frac{1}{MA+MB}\right]^{1/2} \text{--38a}$$

Let $K = 1.0659\,x10^{-4}\left[\frac{1}{MA+MB}\right]^{1/2}$ --38b

Equation (38) becomes:

$$\wp ab = \frac{KT^{3/2}}{\rho_A} \text{--39}$$

Substituting equation (39) into (26) gives:

$$\frac{NA}{Ar} = \frac{-KT^{3/2}dCA}{PAdx} \text{--40}$$

Collecting like terms we have

$\frac{-KT^{3/2}dCA}{N_A P_A} = \frac{dx}{A_T}$ --41

onsidering the transport area as a square grid with sides x gives

$\frac{-KT^{3/2}dCA}{N_A P_A} = \frac{dx}{X^2}$ --42

om the box model of air duality modeling (Rally 1980)

$A = \frac{QA}{\bar{U} WD}$ --43

here:

= is the mean wind velocity, mls

= is the length of the transport area, M.

= is the width of the transport area, M

A = is the emission rate of species A, g/s.

cCare (1980) however concluded that the rate of emission of pollutant species is equal to the rate at hich they are transported downwind, all prevailing meteorological and atmospheric conditions being constant. Thus, it can be assumed that QA is equal to mass transport rate, N_A

Therefore:

$CA = \frac{N_A}{\bar{U} WD}$ --44

⇨ $NA = CA\bar{u}WD$

Taking the same square transport area with length and width equal to x meters.

$NA = CA\bar{u}X^2$ --45

$\frac{-KT^{3/2}dcA}{\left(CA\bar{u}X^2\right)P_A} = \frac{dx}{X^2}$ (By substituting equation (45) into (42) eliminating x^2 from both sides of he equation yields:

$$\frac{dC_A}{C_A} = \frac{\bar{U}P_A}{KT^{3/2}}dx \text{ -- } 46$$

Integrating equation (46) with limits between X_1 and X_2 and O and C_A gives

$$\int_{O}^{CA}\frac{dC_A}{C_A} = \frac{-\bar{U}P_A}{KT^{3/2}}\int_{x_1}^{x_2}dx$$

$$\therefore \ln C_A = \frac{-\bar{U}P_A\Delta X}{KT^{3/2}} \text{ -- } 47$$

$$C_A = \exp\left[\frac{-\bar{u}P_A}{KT^{3/3}}\right] \text{ -- } 48$$

For this study, air is regarded as a mixture of the basic components of pure air and the air pollutants

$$Co = Cpollutants = \exp\left[\frac{-u\,Ppollutants}{KT^{3/2}}\right] \text{ ---------------------------------- } 49$$

Where:

$P_{pollutants} = P_{ATM} - P_{PDA}$

P_{ATM} = Atmospheric pressure, KPa

P_{PDA} = Partial pressure of pure components of air, 100.0 KPa

From the relationship between vapour pressure and temperature, developed by Antoine

$$\ln P = A - \frac{B}{T + D} \text{ -- } 50$$

Where:

A,B and D are Antoine constants.

T = temperature (K)

P = vapour pressure (mmHg)

Note that Antoine constants for water are:

A = 18.3036

B = 3816.44

D = -46.13.

From the literature, a relationship between vapour pressure, relative humidity and temperature is obtained, Chigbua, 1997.

Where:

$$T = \frac{3.99x10^{2} H}{0.012H - \ln P} \quad \text{--}51$$

Substituting equation (50) into (42) gives:

$$T = \frac{3.99x10^{2} H}{0.012H - \left(A - \frac{B}{T+D}\right)} \quad \text{--}52$$

Substituting equation (52) into (49), we obtain:

$$C_{POLLUTANTS} = Co = \exp\left[\frac{-\bar{u} P_{POLLUTANTS}\left(1.32x10^{-3}\right)H^{3/2}\left(A - \frac{B}{T+D}\right)^{3/2}}{7.97x10^{3} KH^{3/2}}\right] \quad \text{-----}53$$

By substituting equation (53) and (22) into equation (24) gives:

$$C = \exp\left[\frac{-\bar{u} P_{POLLUTANTS}\left(1.32x10^{-3}\right)H^{3/2}\left(A - \frac{B}{T+D}\right)^{3/2}}{7.97x10^{3} KH^{3/2}}\right] - \frac{\rho}{2\pi\delta^{2} y\delta z Co} \exp$$

$$\left[\frac{-1}{2}\left(\frac{Xp-Xr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Yp-Yr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Zp-Zr}{\delta z}\right)^{2}\right] \qquad 54$$

From the relationship:

$$\frac{Uz}{Ug}=\frac{hz}{hg} \quad \text{---} 55$$

We have $Uz=Ug\left(\frac{hz}{hg}\right)$ --56

Where:

Ug = wind velocity at height z,

Ug = wind velocity at ground station height.

hz = height Z.

hg = ground station height usually (10m).

replacing $\bar{u}$ in equation (54) with Uz (equation 55), equation 54 becomes:

$$C=\exp\left[\frac{-\bar{u}_{Z}\,P_{POLLUTANTS}\left(1.32x10^{-3}\right)H^{3/2}\left(A-\frac{B}{T+D}\right)^{3/2}}{7.97x10^{3}KH^{3/2}}\right]-\frac{\rho}{2\pi\delta^{2}y\delta zCo}\exp$$

$$\left[\frac{-1}{2}\left(\frac{Xp-Xr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Yp-Yr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Zp-Zr}{\delta z}\right)^{2}\right] \quad \text{----------------} 57$$

$$\therefore C=\exp\left[\frac{-u_{g}\,hzP_{POLLUTANTS}\left(1.32x10^{-3}\right)H^{3/2}\left(A-\frac{B}{T+B}\right)^{3/2}}{7.97x10^{3}KH^{3/2}}\right]-\frac{\rho}{2\pi\delta^{2}y\delta zCo}\exp$$

$$C = \exp\left[\frac{-\bar{u}\,P_{POLLUTANTS}\left(1.32\,x10^{-3}\right)H^{3/2}\left(A-\frac{B}{T+D}\right)^{1/2}}{7.97\,x10^{3}\,KH^{3/2}}\right]\frac{\rho}{2\pi\delta^{2}y\delta zCo}\exp$$

$$\left[\frac{-1}{2}\left(\frac{Xp-Xr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Yp-Yr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Zp-Zr}{\delta z}\right)^{2}\right] \qquad 54$$

From the relationship:

$$\frac{Uz}{Ug}=\frac{hz}{hg} \quad \text{---}55$$

We have $Uz=Ug\left(\frac{hz}{hg}\right)$ --56

Where:

Ug = wind velocity at height z,

Ug = wind velocity at ground station height.

hz = height Z.

hg = ground station height usually (10m).

replacing $\bar{u}$ in equation (54) with Uz (equation 55), equation 54 becomes

$$C=\exp\left[\frac{-u_{Z}\,P_{POLLUTANTS}\left(1.32x10^{-3}\right)H^{3/2}\left(A-\frac{B}{T+D}\right)^{3/2}}{7.97x10^{3}\,KH^{3/2}}\right]-\frac{\rho}{2\pi\delta^{2}y\delta zCo}\exp$$

$$\left[\frac{-1}{2}\left(\frac{Xp-Xr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Yp-Yr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Zp-Zr}{\delta z}\right)^{2}\right] \text{-----------------}57$$

$$\therefore C = \exp\left[\frac{-u_g\, hzP_{POLLUTANTS}\left(1.32x10^{-3}\right)H^{3/2}\left(A-\frac{B}{T+B}\right)^{3/2}}{7.97x10^{3}KH^{3/2}}\right] - \frac{\rho}{2\pi\delta^{2} y\delta z C_o}\exp$$

$$\left[\frac{-1}{2}\left(\frac{Xp-Xr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Yp-Yr}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Zp-Zr}{\delta z}\right)^{2}\right] \text{-------------------}58$$

But $X_r = Y_r = Z_r = O$

Equating 58 there reduces to :

$$\therefore C = \exp\left[\frac{-u_g\, hzP_{POLLUTANTS}\left(1.32x10^{-3}\right)H^{3/2}\left(A-\frac{B}{T+D}\right)^{3/2}}{7.97x10^{3}KH^{3/2} * hg}\right] - \frac{\rho}{2\pi\delta^{2} y\delta z C_o}\exp$$

$$\left[\frac{-1}{2}\left(\frac{Xp}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Yp}{\delta y}\right)^{2}\right]\exp\left[\frac{-1}{2}\left(\frac{Zp}{\delta z}\right)^{2}\right] \text{----------------------}59$$

Equation 59 is the modeling equation for calculating atmospheric pollutants concentration at specified distances above the ground level

Where δ can be evaluated from the relationship $\delta = (L^*X1 + MX)^N$, developed by Gifford, 1975.

Where δ = urban dispersion coefficient, m

X = downwind distance, KM

The constants L, M and N for use in equation 59 above are

Pasquill	For obtaining δz			For obtaining δy		
stability class	L	M	N	L	M	N
D	220	0.00	0.00	220	0.40	-0.50

CHAPTER FIVE

5.0 RESULTS, DISCUSSION AND CONCLUSION

5.1 RESULTS

The following i.e the wind speed, relative humidity, temperature and pressure were colleted from the Nigeria Meteorological Agency (NIMET) Lagos for calabar metropolis

5.1.1 Collected data.

Table 5.1: Monthly record of meteorological observation for year 2002

Month	Temperature (°C)	Relative humidity (%)	Pressure (mbar)	Wind speed (m/s)
January	27.0	79.0	1003.0	7.6
February	28.0	75.0	1002.0	7.4
March	27.6	82.0	1002.5	7.2
April	26.5	72.0	1002.9	7.4
May	26.6	76.0	1003.5	7.6
June	26.5	75.0	1005.2	7.5
July	25.7	78.0	1005.1	7.4
August	24.8	93.0	1006.2	7.4
September	25.6	73.0	1004.5	7.6
October	25.7	80.0	1004.0	7.2
November	26.7	78.0	1003.2	7.1
December	27.1	79.0	1002.9	5.8

5.1.2 Simulated Result

Table 5.2 Concentration of air pollutant for the month of January

Concentration for January 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.61806473
2	100	0.41194164
3	150	0.27455959
4	200	0.18299322
5	250	0.12196361
6	300	0.08128702
7	350	0.05417568
8	400	0.03610552
9	450	0.02406119
10	500	0.01603291
11	550	0.01068114
12	600	0.0071129
13	650	0.00473323
14	700	0.00314506
15	750	0.00208382
16	800	0.00137288
17	850	0.0008942
18	900	0.00056869
19	950	0.00034301
20	1000	0.00018082

Table 5.3 Concentration of air pollutant for the month of February

Concentration for February 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.61978646
2	100	0.4177059
3	150	0.28151294
4	200	0.18972465
5	250	0.12786348
6	300	0.08617189
7	350	0.05807356
8	400	0.03913633
9	450	0.02637311
10	500	0.01777075
11	550	0.01197242
12	600	0.00806365
13	650	0.00542806
14	700	0.00365013
15	750	0.00244972
16	800	0.00163782
17	850	0.00108684
18	900	0.00071047
19	950	0.0004501
20	1000	0.00026564

Table 5.4 Concentration of air pollutant for the month of March

Concentration for March 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.63339783
2	100	0.43136443
3	150	0.29377266
4	200	0.20006741
5	250	0.13625081
6	300	0.09278951
7	350	0.06319078
8	400	0.04303283
9	450	0.02930224
10	500	0.01995415
11	550	0.01358582
12	600	0.00924799
13	650	0.00629275
14	700	0.00427881
15	750	0.00290552
16	800	0.001968
17	850	0.00132656
18	900	0.00088582
19	950	0.00058052
20	1000	0.00036579

Table 5.5 Concentration of air pollutant for the month of April

Concentration for April 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.6184549
2	100	0.6184549
3	150	0.6184549
4	200	0.6184549
5	250	0.6184549
6	300	0.6184549
7	350	0.6184549
8	400	0.6184549
9	450	0.6184549
10	500	0.6184549
11	550	0.6184549
12	600	0.6184549
13	650	0.6184549
14	700	0.6184549
15	750	0.6184549
16	800	0.6184549
17	850	0.6184549
18	900	0.6184549
19	950	0.6184549
20	1000	0.6184549

Table 5.6 Concentration of air pollutant for the month of May

Concentration for May 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.615679
2	100	0.41025938
3	150	0.27337693
4	200	0.18216404
5	250	0.12138368
6	300	0.08088231
7	350	0.05389382
8	400	0.03590958
9	450	0.02392519
10	500	0.01593867
11	550	0.01061591
12	600	0.00706787
13	650	0.00470205
14	700	0.00312351
15	750	0.00206889
16	800	0.0013625
17	850	0.00088691
18	900	0.00056347
19	950	0.00033914
20	1000	0.00017778

Table 5.7 Concentration of air pollutant for the month of June

Concentration for June 2002		
S/No	Altitude. hz (m)	Concentration (kg/m^3)
1	50	0.61766578
2	100	0.41347576
3	150	0.27678704
4	200	0.18528446
5	250	0.12403073
6	300	0.08302627
7	350	0.05557694
8	400	0.03720153
9	450	0.02490024
10	500	0.0166649
11	550	0.01115118
12	600	0.0074591
13	650	0.00498611
14	700	0.00332875
15	750	0.00221679
16	800	0.00146911
17	850	0.0009642
18	900	0.00062031
19	950	0.00038223
20	1000	0.00021224

Table 5.8 Concentration of air pollutant for the month of July

Concentration for July 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.62491056
2	100	0.42058852
3	150	0.28307154
4	200	0.19051653
5	250	0.12822316
6	300	0.08629718
7	350	0.05807917
8	400	0.03908705
9	450	0.02630419
10	500	0.01770025
11	550	0.0119087
12	600	0.00800978
13	650	0.00538436
14	700	0.00361566
15	750	0.00242304
16	800	0.00161743
17	850	0.00107134
18	900	0.00069865
19	950	0.00044094
20	1000	0.00025828

Table 5.9 Concentration of air pollutant for the month of August

Concentration for August 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.63677266
2	100	0.63677266
3	150	0.63677266
4	200	0.63677266
5	250	0.63677266
6	300	0.63677266
7	350	0.63677266
8	400	0.63677266
9	450	0.63677266
10	500	0.63677266
11	550	0.63677266
12	600	0.63677266
13	650	0.63677266
14	700	0.63677266
15	750	0.63677266
16	800	0.63677266
17	850	0.63677266
18	900	0.63677266
19	950	0.63677266
20	1000	0.63677266

Table 5.10 Concentration of air pollutant for the month of September

Concentration for September 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.61379149
2	100	0.40881791
3	150	0.27229404
4	200	0.18136094
5	250	0.12079424
6	300	0.08045336
7	350	0.0535839
8	400	0.035687
9	450	0.02376617
10	500	0.01582555
11	550	0.01053575
12	600	0.00701125
13	650	0.00466215
14	700	0.00309543
15	750	0.00204913
16	800	0.00134854
17	850	0.00087697
18	900	0.00055626
19	950	0.00033373
20	1000	0.00017346

Table 5.11 Concentration of air pollutant for the month of October

Concentration for October 2002

S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.63354444
2	100	0.43109713
3	150	0.2933408
4	200	0. 1996033
5	250	0.13581906
6	300	0.09241676
7	350	0.06288335
8	400	0.042787
9	450	0.02911201
10	500	0.01980633
11	550	0.01347364
12	600	0.00916373
13	650	0.00622999
14	700	0.00423237
15	750	0.00287132
16	800	0.00194289
17	850	0.00130812
18	900	0.00087222
19	950	0.00057036
20	1000	0.000358

Table 5.12 Concentration of air pollutant for the month of November

Concentration for November 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.63420463
2	100	0.43409689
3	150	0.29712778
4	200	0.20337513
5	250	0.13920356
6	300	0.09527965
7	350	0.06521469
8	400	0.04463576
9	450	0.03054967
10	500	0.02090766
11	550	0.01430739
12	600	0.00978894
13	650	0.00669525
14	700	0.00457648
15	750	0.00312468
16	800	0.00212893
17	850	0.00144471
18	900	0.00097292
19	950	0.00064542
20	1000	0.00041525

Table 5.13 Concentration of air pollutant for the month of December

Concentration for December 2002		
S/No	Altitude, hz (m)	Concentration (kg/m^3)
1	50	0.68028519
2	100	0.68028519
3	150	0.68028519
4	200	0.68028519
5	250	0.68028519
6	300	0.68028519
7	350	0.68028519
8	400	0.68028519
9	450	0.68028519
10	500	0.68028519
11	550	0.68028519
12	600	0.68028519
13	650	0.68028519
14	700	0.68028519
15	750	0.68028519
16	800	0.68028519
17	850	0.68028519
18	900	0.68028519
19	950	0.68028519
20	1000	0.68028519

Fig.2 Concentration against Altitude for january 2002

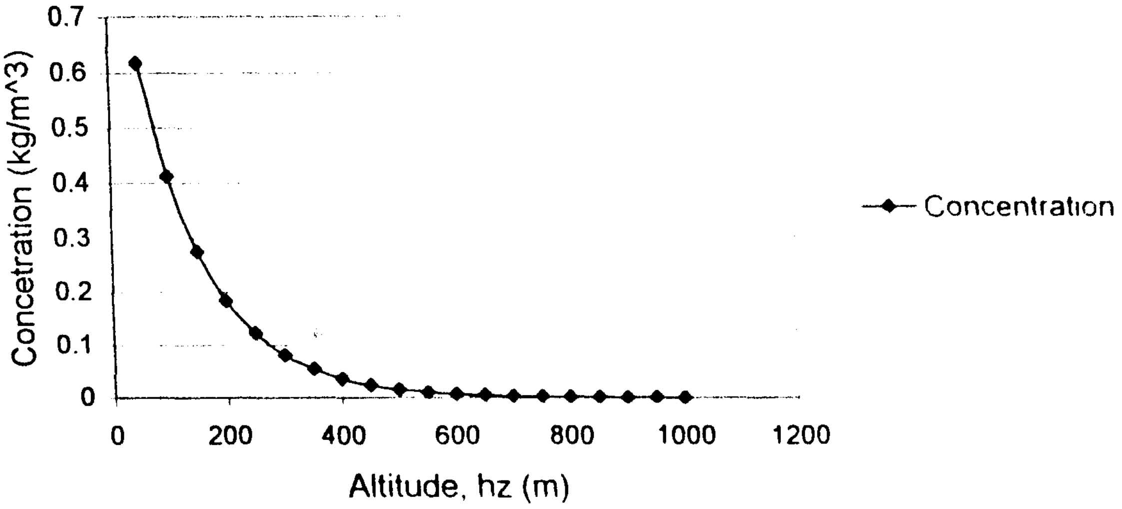


Fig.3 Concentration against Altitude for february2002

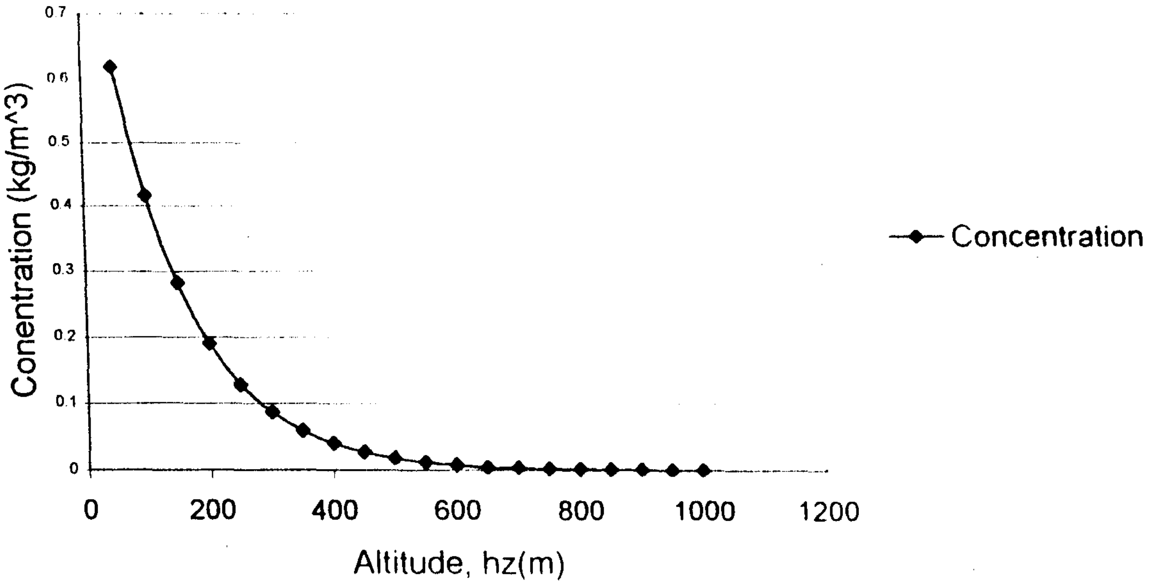


Fig .4 Concentration against Altitude for march 2002

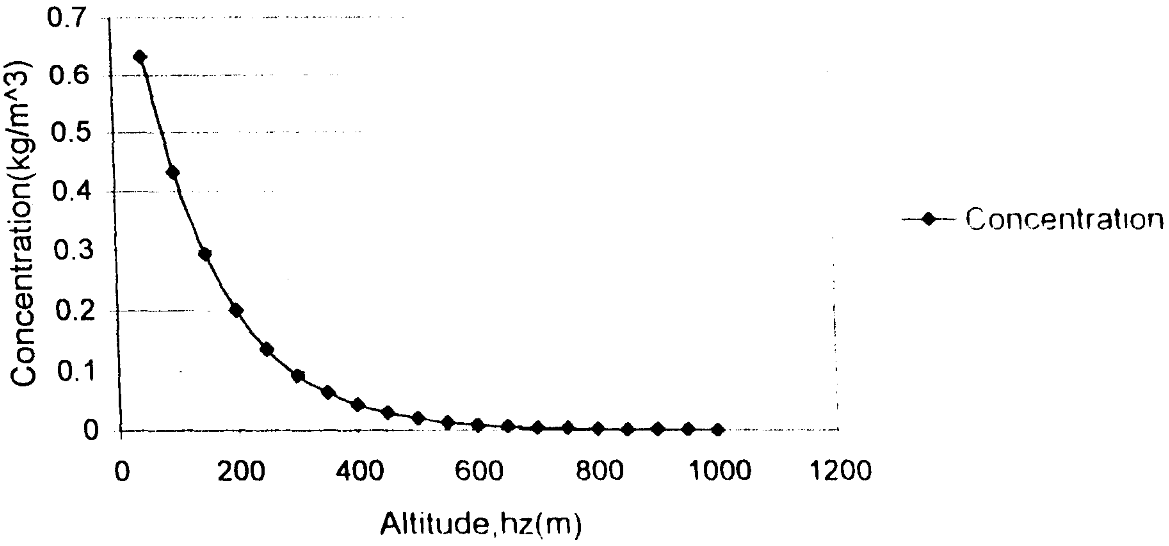


Fig. 5 Concentration against Altitude for April 2002

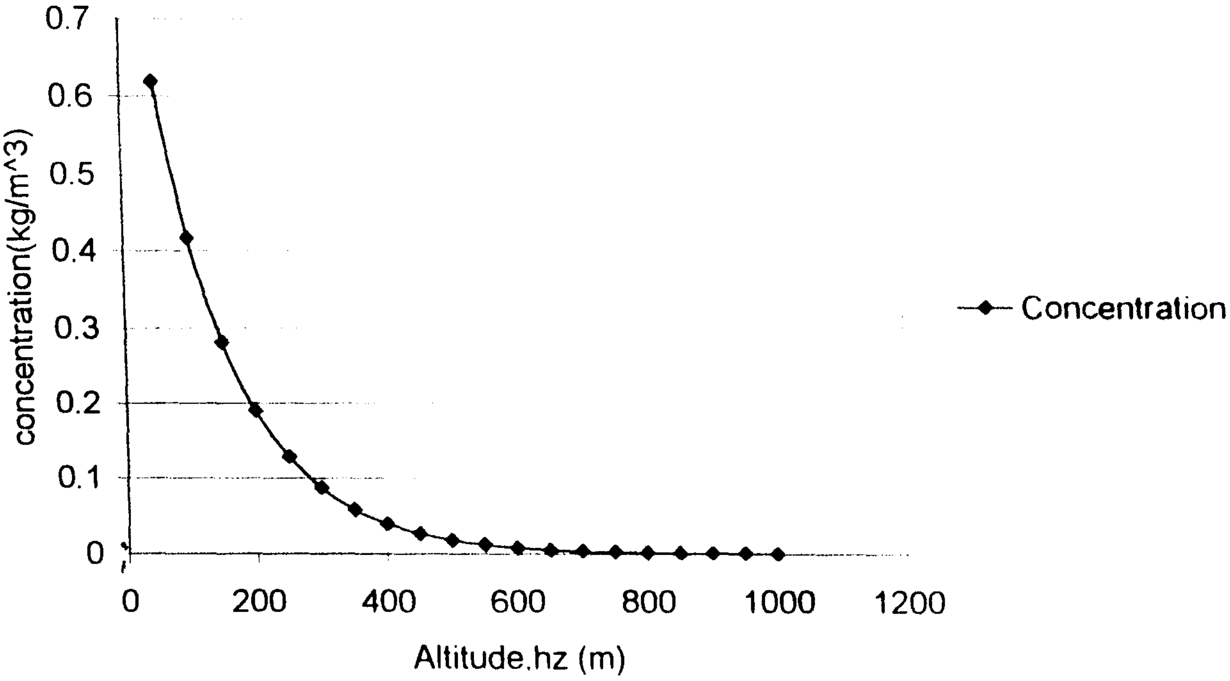


Fig.6 Concentration against Altitude for May 2002

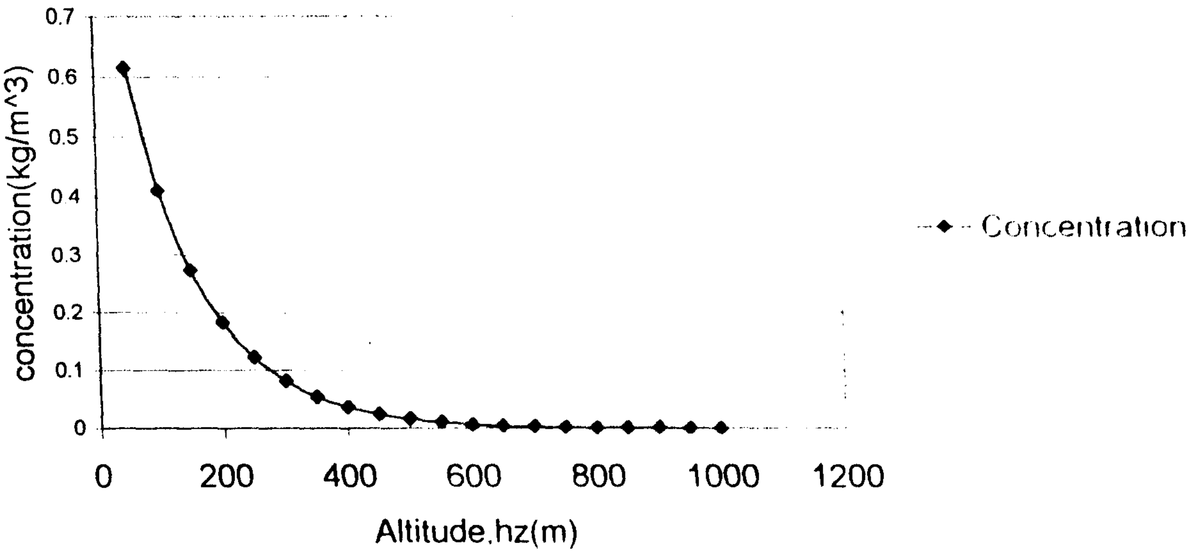


Fig.7 Concentration against Altitude for June 2002

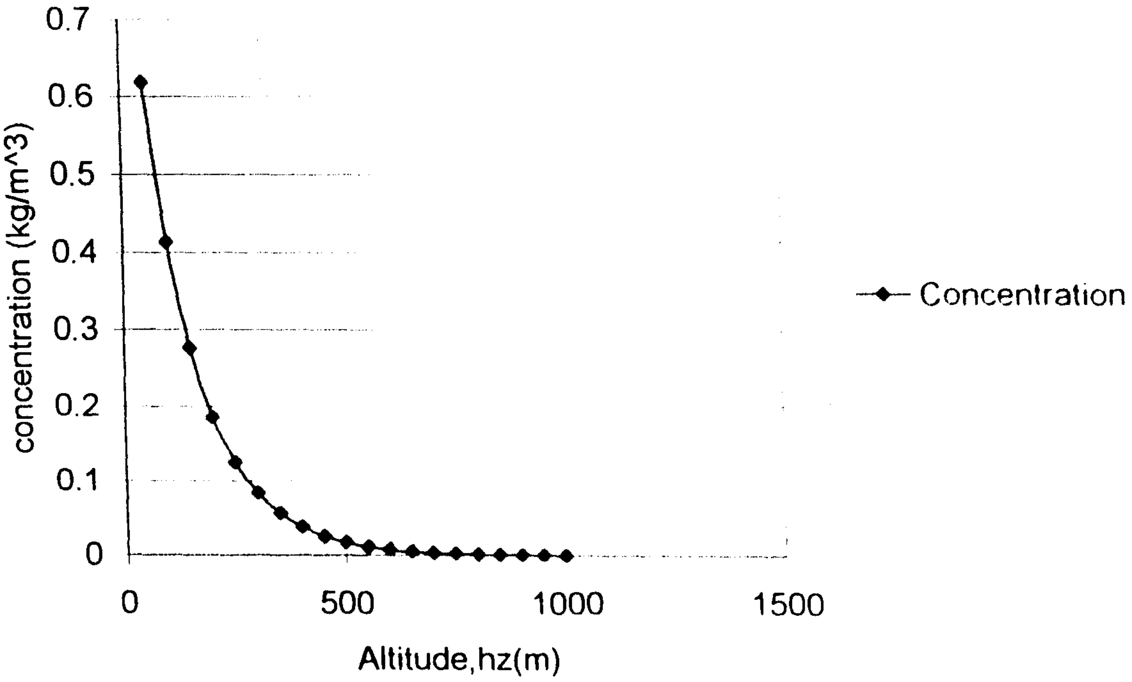


Fig.8 Concentration against Altitude for July 2002

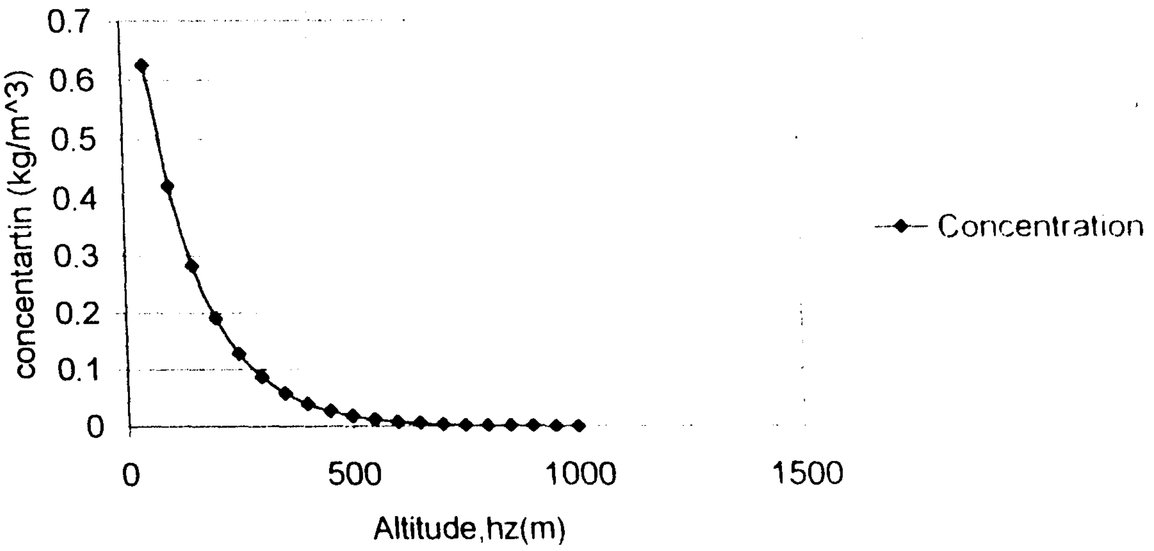


Fig.9 Concentration aganist for October 2002

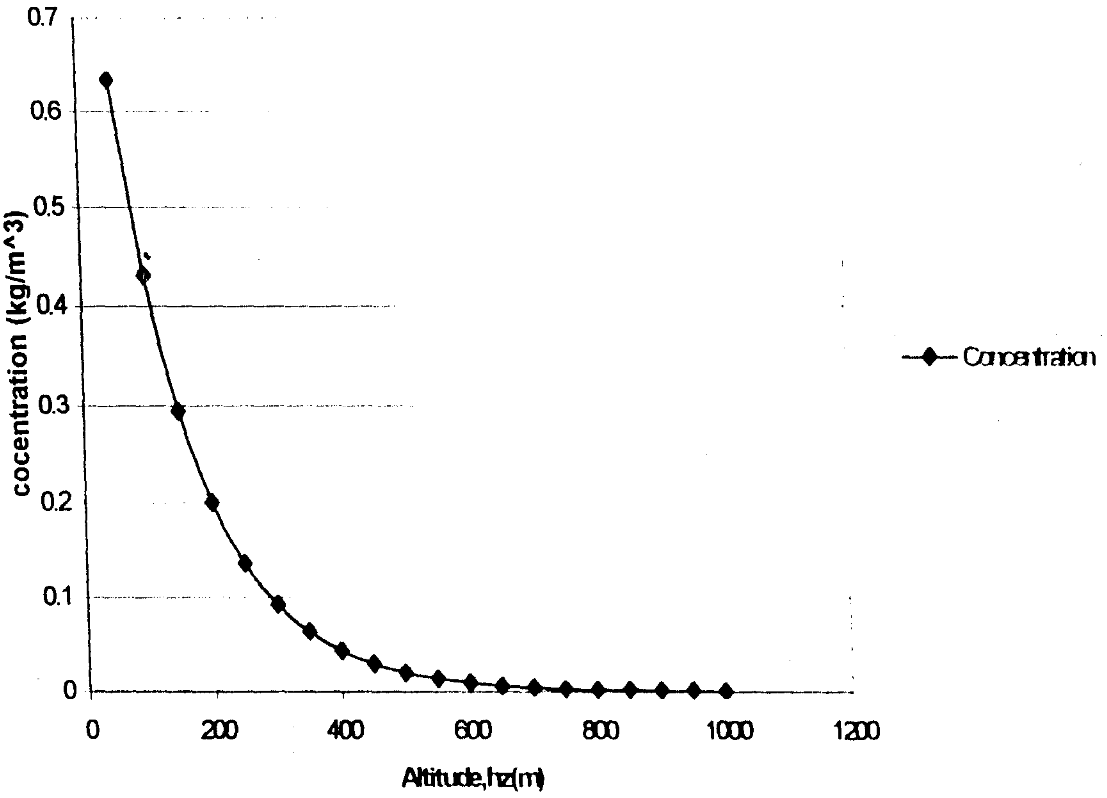


Fig.10 Concentration against Altitude for September 2002

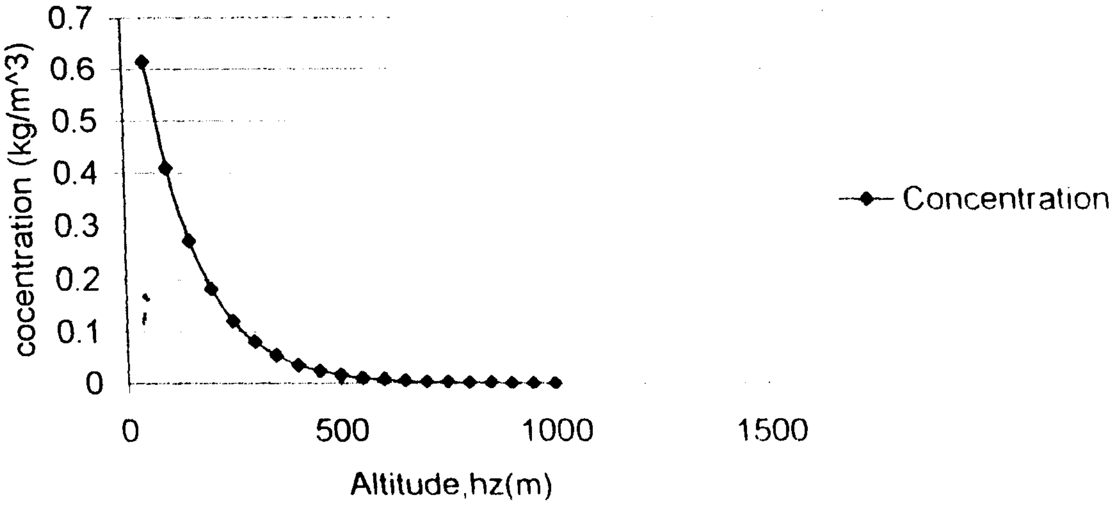


Fig.11 Concentration aganist for October 2002

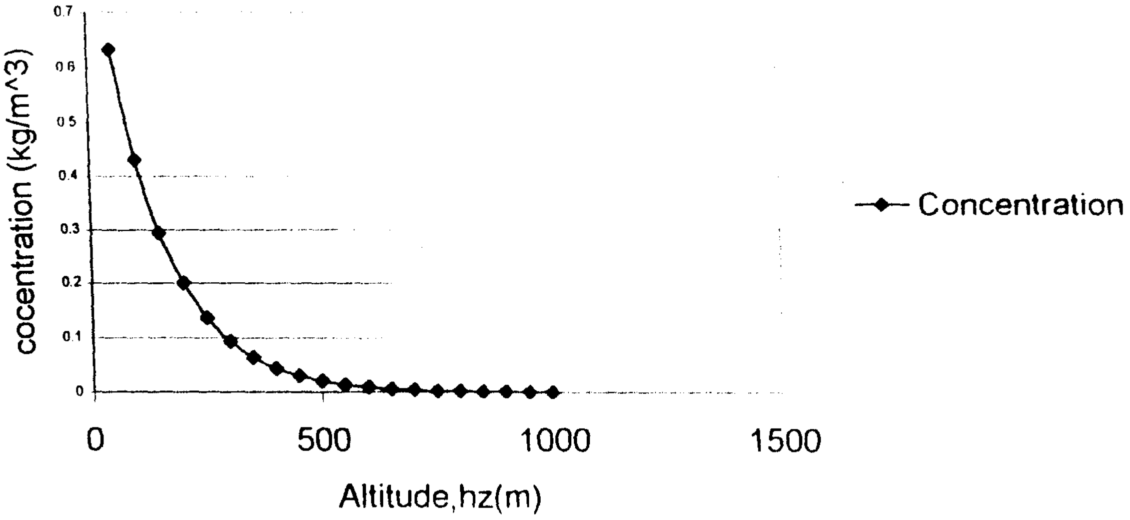


Fig.12 Concentration against Altitude for November 2002

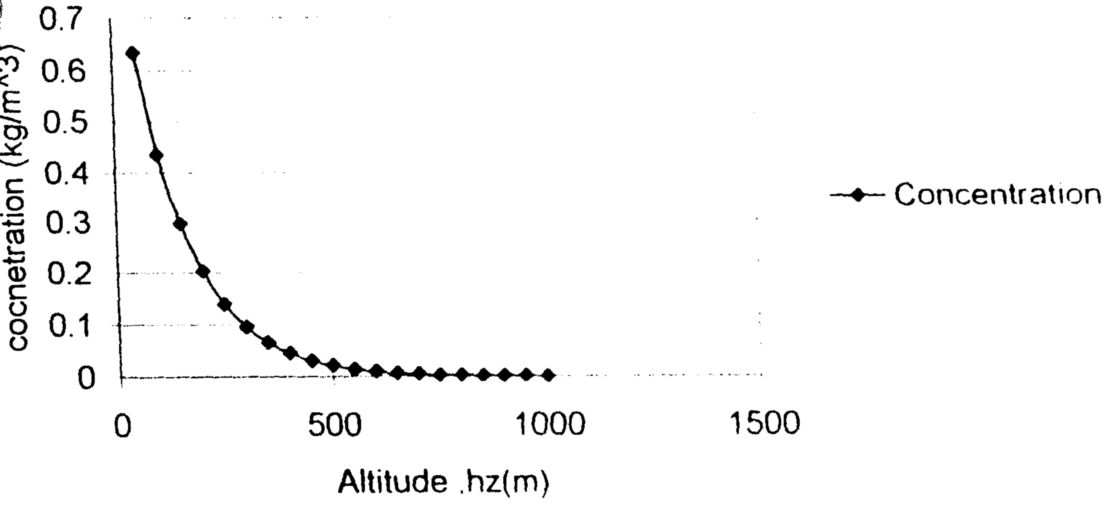
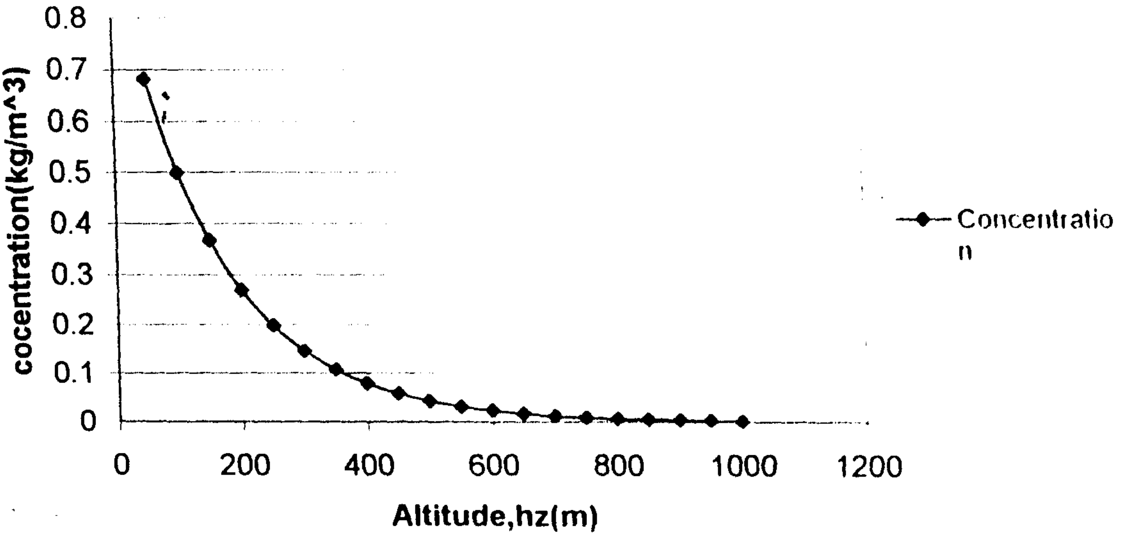


Fig.13 Concentration against Altitude for December 2002



DISCUSSION OF RESULTS

bal worming refers to an increase in the earth's temperature which in turn causes the ease in the temperature of the earth's surface due to emission of CO_2 and other green house es, into the atmosphere (Olabanji, 2003) The inhabitants around the Niger-Delta area suffer ardous effect as a result of pollutants released into the air and the major air pollutants are es and particulate matters (George, 2000) Table 5 1 is the collected data for year 2002, for labar metropolis i.e. the temperature, pressure, humidity and wind-speed The productive odel equation which was developed from the based on the modified principle of Gausian spersion equation.

he simulated result shows the same trend i.e. an increase in altitude causes a decrease in the pollutants concentrations from the point of emission For example table 5 2 for the month of January at a distance of 50m has a concentration of 0 618065Kg/m^3 but on dispersion by wind and other meteorological factors. It reduces to 0 411942Kg/m^3 at a distance of 100m as the altitude increase the concentration decreases and at the final altitude 1000m have a concentration of 0.000181Kg/m^3 for the month of December

The graphical representation also shows a decrease in concentration of pollutants with respect to increase in altitude. The graphs in figure 2 13 shows a pattern which corresponds to the predictive model.

As the released pollutants travel upwards, they are being acted upon by weather conditions such as dispersion. With increased in altitude, weather conditions that act on the pollutants are more severe therefore, greatly reduces the pollutants concentration Hence, it can deduce that the simulated results agreed with predictive model Concentrating that the model actually shows how concentration reduces with increasing altitude, thus configuring the validity of the predictive model.

3. CONCLUSION

he following can be deduced from this project work;

The concentration of the pollutants is determined by the predictive model using meteorological ata.

As a result of pollutants been released into the atmosphere the rate of concentration decreases with increasing altitude

The simulated result confirms the validity of the predictive model equation. an increase in altitude causes a decrease in altitude of the pollutants

4 RECOMMENDATIONS

o develop mitigation measure that will reduce the emission of these pollutants to the bearest inimum, the followings would be recommended

- The removal of gaseous constituents from the atmosphere be done by adsorption process absorption process and by combustion And for particulate matter, can be done by the use of a cyclone to remove the solid and liquid particles from gas stream
- Numerical weather forecast should be used for studying current and future atmospheric conditions.
- Meteorologist should conduct more research into the manner in which contaminants are transported and diffused within the atmosphere under various conditions
- Legal authorities (Federal Ministry of Environment) enforcing recommended limits Making sure that industries that emit these pollutants adhere to the regulations

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APPENDIX

Computer program

```
ption Explicit
rivate arrayUg_(5), arrayH_(5), arrayT_(5), arrayPatm (5),
rrayxp_(5) As Double
Dim bisi(12) As Concent
Private i As Integer
Private A_, B_, D_, Da_, Ma , Mb , hg  As Double
Private Ly, Lz, My, Mz, Ny, Nz As Double
Private Ug_, H_, T_, Patm , xp  As Double
Private x, y, z, hz As Double
Private year As Integer

Private Sub Form_Load()
Me.Width = 10035
Me.Height = 6465
addComboItems
setTitle
textFlds
year = 0
End Sub
Private Function getValues(Index As Integer) As Double
Dim r As Integer
Dim ju As Integer
ju = Index

Ug_ = val(Ug(ju%))
H_ = val(H(ju%))
T_ = val(T(ju%))
Patm_ = val(Patm(ju%))
xp_ = val(Ta(ju%))

Da_ = val(Da(0))
A_ = val(A(0))
B_ = val(B(0))
D_ = val(D(0))
Ma_ = val(Ma(0))
Mb_ = val(Mb(0))
hg_ = val(hg(0))

Ly = val(dyV(0))
Lz = val(dzV(0))
My = val(dyV(1))
Mz = val(dzV(1))
Ny = val(dyV(2))
Nz = val(dzV(2))

hz = 50
For r = 0 To 19
x = hz / 1000
answer(r, 0) = Conc
hz = hz + 50
Next r
getValues = 0
End Function
```

```
ivate Sub Jan_Label(Index As Integer)
 = Index
rayUg_(0) = 7.2
rayUg_(1) = 7.6

rayH_(0) = 76
rayH_(1) = 79

rayT_(0) = 299.5
rayT_(1) = 300

rrayPatm_(0) = 1.0057
rrayPatm_(1) = 1.003

Ug(i%).Text = arrayUg_(i%)
H(i%).Text = arrayH_(i%)
T(i%).Text = arrayT_(i%)
Patm(i%).Text = arrayPatm_(i%)
Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)
End Sub
Private Sub Feb_Label(Index As Integer)
i% = Index
arrayUg_(0) = 7.4
arrayUg_(1) = 7.4

arrayH_(0) = 71
arrayH_(1) = 75

arrayT_(0) = 299.5
arrayT_(1) = 301

arrayPatm_(0) = 1.0058
arrayPatm_(1) = 1.002


Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)

End Sub

Private Sub Mar_Label(i%)
arrayUg_(0) = 7.3
arrayUg_(1) = 7.2

arrayH_(0) = 75
arrayH_(1) = 82

arrayT_(0) = 299.4
arrayT_(1) = 300.6

arrayPatm_(0) = 1.0047
arrayPatm_(1) = 1.0025
```

```
g(0).Text = arrayUg_(i%)
(0).Text = arrayH_(i%)
(0).Text = arrayT_(i%)
atm(0).Text = arrayPatm_(i%)

nd Sub

Private Sub Apr_Label(i%)
arrayUg_(0) = 7.6
arrayUg_(1) = 7.4

arrayH_(0) = 76
arrayH_(1) = 72

arrayT_(0) = 300
arrayT_(1) = 299.5

arrayPatm_(0) = 1.006
arrayPatm_(1) = 1.0029


Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)

End Sub

Private Sub May_Label(i%)
arrayUg_(0) = 7.2
arrayUg_(1) = 7.6

arrayH_(0) = 74
arrayH_(1) = 76

arrayT_(0) = 299.4
arrayT_(1) = 299.6

arrayPatm_(0) = 1.0072
arrayPatm_(1) = 1.0035


Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)

End Sub

Private Sub Jun_Label(i%)
arrayUg_(0) = 7.4
arrayUg_(1) = 7.5

arrayH_(0) = 86
arrayH_(1) = 75
```

```
arrayT_(0) = 299.1
arrayT_(1) = 299.5

arrayPatm_(0) = 1.0091
arrayPatm_(1) = 1.0052


Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)
End Sub

Private Sub Jul_Label(i%)
arrayUg_(0) = 5.8
arrayUg_(1) = 7.4

arrayH_(0) = 90
arrayH_(1) = 78

arrayT_(0) = 298.1
arrayT_(1) = 298.7

arrayPatm_(0) = 1.0096
arrayPatm_(1) = 1.0051


Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)
End Sub

Private Sub Aug_Label(i%)
arrayUg_(0) = 4.4
arrayUg_(1) = 7.4

arrayH_(0) = 91
arrayH_(1) = 93

arrayT_(0) = 298.4
arrayT_(1) = 297.4

arrayPatm_(0) = 1.0092
arrayPatm_(1) = 1.0062

Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)
End Sub
Private Sub Sep_Label(i%)
arrayUg_(0) = 6.6
arrayUg_(1) = 7.6

arrayH_(0) = 90
arrayH_(1) = 73
```

```
arrayT_(0) = 297.8
arrayT_(1) = 298.6

arrayPatm_(0) = 1.008
arrayPatm_(1) = 1.0045

Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)
End Sub
Private Sub Oct_Label(i%)
arrayUg_(0) = 4.6
arrayUg_(1) = 7.2

arrayH_(0) = 87
arrayH_(1) = 80

arrayT_(0) = 298#
arrayT_(1) = 298.7

arrayPatm_(0) = 1.008
arrayPatm_(1) = 1.0045


Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)
End Sub

Private Sub Nov_Label(i%)
arrayUg_(0) = 2#
arrayUg_(1) = 7.1

arrayH_(0) = 86
arrayH_(1) = 78

arrayT_(0) = 298.9
arrayT_(1) = 299.7

arrayPatm_(0) = 1.0074
arrayPatm_(1) = 1.0032

Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)
End Sub

Private Sub Dec_Label(i%)
arrayUg_(0) = 3.4
arrayUg_(1) = 5.8

arrayH_(0) = 82
arrayH_(1) = 79
```

```
arrayT_(0) = 299.7
arrayT_(1) = 300.1

arrayPatm_(0) = 1.0063
arrayPatm_(1) = 1.0029


Ug(0).Text = arrayUg_(i%)
H(0).Text = arrayH_(i%)
T(0).Text = arrayT_(i%)
Patm(0).Text = arrayPatm_(i%)
End Sub
Private Sub reset_Click()
For i = 0 To 4
Ug(i%).Text = ""
H(i%).Text = ""
T(i%).Text = ""
'Ta(i%).Text = ""
Patm(i%).Text = ""
Next i
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 1
If (Check1(j).Value = 1) Then
chec = j
getValues (j)
vol = Vs
MsgBox "Sim Complete"
whatsta = (year + 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
```