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SCHOOL OF SCIENCE AND TECHNOLOGY

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COURSE TITLE: AIR AND NOISE POLLUTION

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UNIT 1: AIR POLLUTION AS AN ENVIRONMENTAL PROBLEM

CONTENTS

1.0 Introduction

Air pollution is defined as the contamination of air by discharge of harmful substances, which can cause health problems including burning eyes and nose, itchy irritated throat and breathing problems (USEPA 1994). It was also reported that some chemicals found in polluted air could cause cancer, birth defects brain and nerve damage, and long term injury to the lungs and breathing passages in certain circumstances. The concentrations of such chemicals beyond a limit, and an exposure over a certain period are extremely dangerous and can cause severe injury or even death. Air pollution can be classified into natural air pollution which includes wind blown dust, volcanic ash, and gases, smoke and trace gases from forest fires, and anthropogenic air pollution which includes products of combustion such as nitrogen oxides (NO_x), carbon oxides (Co_x), sulphur dioxide (SO_2).

The sole concern of this study material is to provide a lecture series in air and noise pollution. This does not mean that other pollution types are unimportant; it is only because we do not want you to be confused with much matter at a time. You will learn about the other types in another lecture material. We will take these one at a time.

2.0 Objectives

The objectives of this section of the study note are to make you to:

a. Describe the history of air pollution;

b. Mention some sources of pollution in Nigeria; and

c. Mention the percentage contribution of emissions to air pollution in Nigeria

3.0 Main Content

3.1 Briefs on Air Pollution outside Nigeria

(a) Air pollution, particularly in cities, is certainly not a new problem. Back in the Middle Ages the use of coal in cities such as London was beginning to escalate. The problems of poor urban air quality even as early as the end of the 16th century are well documented.

In the Europe, the Industrial Revolution during the 18th and 19th centuries was based on the use of coal. Industries were often located in towns and cities, and together with the burning of coal in homes for domestic heat, urban air pollution levels often reached very high levels. During foggy conditions, pollution levels escalated and urban smogs (smoke and fog) were formed. These often brought cities to a halt, disrupting traffic but more dangerously causing death rates to dramatically rise. The effects of this pollution on buildings and vegetation also became obvious. The 1875 Public Health Act in the United Kingdom contained a smoke abatement section to try and reduce smoke pollution in urban areas.

(b) During the first part of the 20th century, tighter industrial controls lead to a reduction in smog pollution in urban areas. The 1926 Smoke Abatement Act was aimed at reducing smoke emissions from industrial sources, but despite the declining importance of coal as a domestic fuel, pollution from domestic sources remained significant.

(c) The Great London Smog of 1952, which resulted in around 4,000 extra deaths in the city, led to the introduction of the Clean Air Acts of 1956 and 1968. These introduced smokeless zones in urban areas, with a tall chimney policy to help disperse industrial air pollutants away from built up areas into the atmosphere.

(d) Following the Clean Air Acts, air quality improvements continued throughout the 1970s. Further regulations were introduced through the 1974 Control of Air Pollution Act. This included regulations for the composition of motor fuel and limits for the sulphur content of industrial fuel oil.

(e) However, during the 1980s the number of motor vehicles in urban areas steadily increased and air quality problems associated with motor vehicles became more prevalent. In the early 1980s, the main interest was the effects of lead pollution on human health, but by the late 1980s and early 1990s, the effects of other motor vehicle pollutants became a major concern. The 1990s have seen the occurrence of wintertime and summertime smogs. These are not caused by smoke and sulphur dioxide pollution but by chemical reactions occurring between motor vehicle pollutants and sunlight. These are known as óphotochemical smogsô.

(f) In 1995, the Government passed its Environment Act, requiring the publication of a National Air quality Strategy to set standards for the regulation of the most common air pollutants. Published in 1997, the National Air Quality Strategy has set commitments for local authorities to achieve new air quality objectives through the UK by 2005. It is reviewed periodically.

3.2 Atmospheric pollution in Nigeria

(a) Atmospheric pollution is also gradually becoming a serious menace in Nigerian cities. Especially in the metropolitan areas, inefficient energy combustion in the transportation system generated high levels of localized air pollution. The recent increase in the importation of second-hand cars and the widespread adoption of the single-engine, ñokadaò motor-cycles for ferrying passengers all over most Nigeria cities have accentuated the general level of air pollution.

Indeed, motor vehicles produce more air pollution than any other single human activity (World Resources Institute 1992). Nearly 50 percent of global carbon monoxide, hydrocarbon, and nitrogen oxide emissions from fossil fuel combustion come from gasoline ï and diesel powered engines. In city centers, especially on highly congested streets, traffic can be responsible for as much as 90 to 95% of the ambient carbon monixde levels, 80 to 90% of the nitrogen oxides and hydrocarbons, and a large portion of the particulates, posing a significant threat to human health and natural resources (Savile 1993).

(b) Heavy reliance on biomass materials as the main energy source for domestic needs, especially by the poor has also been identified, among other things, as partly responsible for a variety of health problems particularly among women. Industrial energy use contributes to the overall level of air pollution. In this regard, the gas flaring in the oil-producing regions of the country represent perhaps the most pernicious of atmosphere pollution in the country. In particular, they have heightened the level of airborne emissions of such pollutants as sulphur dioxide, carbon monoxide and nitrogen oxides, all of which pose serious health hazards in urban areas.

It is claimed that Nigeriaôs carbon dioxide emissions from industrial processes, estimated at 96513 million metric tons in 1992, was the highest in sub-Saharan Africa, excluding the Republic of South Africa. The emission from flared gas alone accounted for more than one half of this figure. Table 1.1 and 1.2 shows the sources of air pollutants in Nigeria, by activities and State, respectively.

Table 1.1. Emission of Air Pollutants in Nigeria

S/N	Sources	Emissions in Gigagrams		
		CO_2	CH_4	N_2O
1	Fossil Fuel combustion	35672.224	5.036	0.915
2	Industrial Process	1874.167	0.000	0.000
3	Oil and gas systems	34625.893	115.946	0.84
4	Biomass burning	0.000	0.28	0.84
5	Land-use changes	0.000	48.414	4.834
6	Savannah burning	0.000	69.711	0.932
7	Agricultural wastes	0.000	47.238	1.555
8	Rice production	0.000	19.110	0.000
9	Ruminants	0.000	364.800	0.000
10	Non-ruminants	0.000	39.210	0.000
11	Animal wastes	0.000	83.603	0.000
12	Municipal solid wastes	0.000	187.251	0.032
13	Agricultural Solids	0.000	0.000	0.000
14	Natural	1038.958	66.225	0.000
15	Coal Mining	0.000	0.480	0.000

Source: Magbagbeola, 1999

Table 1.2: Air Pollutant's Emissions by State in Nigeria

S/N	Sources	Emissions in Gigagrams				
		CO_2	CH_4	N_2O	Total Emission	% of Nigeriaõs Total Emissions
1	Abia	9.13	4.17	0.01	13.31	0.2
2	Akwa Ibom	5733.60	23.30	0.33	5766.23	10.16
3	Anambra (1988)	1277.04	53.36	0.38	1330.68	2.34
4	Bauchi-Gombe	856.72	60.53	0.39	4284.13	7.55
5	Edo-Delta	4282.89	0.71	0.53	4284.13	1.62
6	Benue (1988)	473.07	25.87	0.30	499.24	0.88
7	Bornu-Yobe	609.22	126.40	0.81	736.43	1.30
8	Cross River	599.73	18.18	0.22	618.13	1.09
9	Adamawa -Taraba	456.08	78.96	0.35	535.40	0.94
10	Imo (1988)	3275.17	23.96	0.42	3299.55	5.81
11	Kaduna	1367.07	35.45	0.29	1402.81	2.47
12	Katsina	133.96	24.41	0.28	158.65	0.28
13	Kano-Jigawa	1226.13	38.29	0.66	1265.08	2.23
14	Kwara (1988)	931.04	57.77	0.21	989.02	1.74
15	Lagos	8271.68	24.66	0.56	8296.93	14.62
16	Niger (1988)	444.71	57.87	0.21	502.70	0.98
17	Ogun	1296.90	14.15	0.22	1311.27	2.31
18	Ondo-Ekiti	635.22	26.48	0.32	662.02	1.07
19	Oyo-Ogun	1848.37	40.18	0.52	1889.07	3.33
20	Plateau-Nasarawa	964.47	46.09	0.25	1010.81	1.78

21	Rivers-Bayelsa	20457.7	83.28	0.59	20.541.57	36.18
22	Sokoto-Kebbi Zamfara	634.21	95.00	0.72	729.93	1.29
	Sum of States	55,786.11	971.98	10.51	56,786.60	100.00
	Nigeria	73,312.73	1051.04	10.72	74,374.49	

4.0 Summary

In this Unit, you have learnt that pollution is not pertinent to a particular environment; it is everywhere. What is important is how it is managed. You have learnt about the few stories about pollution here in Nigeria and some other parts of the world. The contribution of each State of Nigeria (or region) to air pollution has been described as well.

5.0 Conclusion

This introduction of air pollution is significant to aid your interest in what you are to meet as you read on. Perhaps you are thinking of how this concerns you. It concerns you because you are a citizen of the world and the problem is transboundary. Emitters of air pollution are not necessarily the sufferers. The next Unit will teach you more of this and pollutantsô attributes.

6.0 Tutor Marked Assignments

(a) Enumerate 3 cases of pollution in any part of the world
(b) Mention the State that contribute highest to the air emissions in Nigeria;
(c) Suggest possible sources of air pollution in State identified in (b) above

7.0 References/Further Reading

USEPA, (1993) Guide to Environmental Issues, Document Number 520/B-94-01 United States Environmental Protection Agency, Washington, DC, USA

USEPA (1994) National Air Quality and Emissions Trends Report, United States Environmental Protection Agency, Washington, DC, USA, pp. 2, 6, 46, 52.

Faiz, A.; Sinha, K.; and Gautam, S. (1994) Air Pollution Characteristics and Trends, discussion paper. The World Bank, Washington, DC, USA

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UNIT 2: POLLUTION AND POLLUTANTS

CONTENT

1.0 Introduction

In Unit 1, you have been given a brief that air pollution is not new. It is not foreign and it is with us here. If you mess, and the odour is stronger than what the environment can hide, then it starts smelling. That shows that the air has been polluted. In this Unit, we get more technical. But do not be afraid, it is still within what your brain can handle. Pollution is the phenomenon but what is a pollutant; the cause of the phenomenon~? Yes it is, and this is the essence of this unit.

2.0 Objectives

By the end of this Unit, you will be able to

(a) Define air pollution
(b) Define pollutants, and
(c) Mention and describe roles of selected chemicals in the atmosphere.

3.0 Main Content

3.1 What is Air Pollution?

The World Health Organisation defines air pollution as ótthe disequilibrium of air caused due to the introduction of foreign elements to humans natural and manmade sources to the air so that it becomes injurious to biological communitiesô.

Air pollution is also the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damages the natural environment, into the atmosphere.

It is also defined as the presence of chemicals in the atmosphere in quantities and duration that are harmful to human health and the environment.

In whatever form we choose to say it; pollution could be caused by either natural phenomenon or human (anthropogenic inducement). For instance, earthquakes and volcanic eruptions are natural phenomena but gas flaring, burning, etc are human induced. Nonetheless, it is necessary to note that man (human) can aggravate natural processes. How? Please take a minute or two to think about this.

3.2 What are Air Pollutants?

These are harmful solid, liquid or gaseous substances that are present in such concentrations in the environment which tend to be injurious to living organisms.

They are also known as substances in the air that can cause harm to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may also be natural or man-made.

3.2.1 Classes of Pollutants

There is no singular view by which pollutants can be classified.

a. <u>Pollutants can be classified as either primary or secondary</u>

Usually, primary pollutants are substances directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories.

Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground level ozone- one of the many secondary pollutants that make up photochemical smog.

Note that some pollutants may be both primary and secondary: that is, they are both emitted directly and formed from other primary pollutants.

b. Pollutants may also be classified as natural or man made

Natural pollutants include dusts or particulate matters, and the man made pollutants include all chemicals that are produced by man.

You must however note that a pollutant is not yet a pollutant until it has caused a significant alteration in the normal gaseous composition of the atmosphere. We can therefore say that all chemicals or natural matters whose introduction is greater than the maximum that the earth can take or absorb are a pollutant.

Meanwhile, it is also useful to note that all chemicals (before they become pollutants) are useful. This table (below) describes some of the chemicals in the troposphere (lower atmosphere) and some of the chemical reactions that happen in the air:

Table 2.1: List of some chemicals and their roles in the atmosphere

Chemical	Formula	Ole in the atmosphere
Carbon dioxide	CO_2	Carbon dioxide is a kind of greenhouse gas. When we breathe, we take in oxygen and breathe out carbon dioxide. Plants and some kinds of microbes use carbon dioxide during photosynthesis to make food. Burning fuels also puts carbon dioxide into the atmosphere
Carbon monoxide	CO	When things burn, they mostly make carbon dioxide. Sometimes they make carbon monoxide, too. Carbon monoxide is a poisonous gas. Volcanoes and car engines make carbon monoxide.
Hydrocarbons	C_xO_y	Hydrocarbons are chemicals made up of hydrogen and carbon atoms. When fuel burns, it puts some hydrocarbons into the air. Hydrocarbons help to make smog, a kind of air pollution
Methane	CH_4	Methane is a kind of greenhouse has.
Nitrogen	N_2	Most of the gas in Earthôs atmosphere is nitrogen. About 4/5ths of the air is nitrogen. The nitrogen cycle explains how nitrogen moves around in the environment. When fuel burns hot, like it does in the engine of a car, nitrogen combines with oxygen to make nitrogen oxides.
Nitrogen Oxides	No & No_2	Nitrogen oxides are a kind of pollution. Burning fuels like gasoline in air makes nitrogen oxides. Most nitrogen oxides come from cars and trucks. They help to make smog. They also mix with water droplets in the air to make nitric acid. Nitric acid is a part of acid rain.
Citric Acid	HNO_3	Nitric acid is part of acid rain. Nitric acid forms when nitrogen oxides mix with water droplets in the air. Nitrogen oxides are a kind of pollution that comes from the engines of cars and trucks
Oxygen & Ozone	O_2 & O_3	About $1/5^{th}$ of the gas in the atmosphere is oxygen. When you breathe, your body uses the

		oxygen to keep you alive. Ozone is a special kind of oxygen that has three atoms instead of two.
PAN (Peroxyacytyl nitrate)	$C_2H_3O_5N$	PAN is a kind of air pollution. Smog has PAN in it. PAN forms when nitrogen dioxide, oxygen, and Volatile Organic Compounds (VOCs) get together.
Smog		Smog is a mixture of smoke and fog. Photochemical smog is a kind of air pollution. It has nitrogen oxides, ozone, VOCs, and PAN in it.
Photodissociation		When a photon of sunlight breaks apart a molecule
Sulphur Oxides	SO_2 & SO_3	Sulphur dioxide and sulphur trioxide are types of pollution. People make them when we burn coal and oil. Volcanoes also give off sulphur oxides. Sulphur dioxide mixes with water droplets in the air to make sulphuric acid. Sulphuric acid is acid rain.
Sulphuric Acid	H_2SO_4	Sulphuric acid is in acid rain. Sulphuric acid in the air is made when sulphur dioxide gas mixes with water droplets. The sulphur dioxide gas comes from volcanoes and from coal and oil that people burn for fuel.

4.0 Summary

Pollution has been defined in this Unit, and so are pollutants. An enumeration has equally been made of a number of chemicals and their roles in the atmosphere. Unfortunately, when these chemicals are abnormally high in concentrations, their loose their names and become pollutants. These are the important information that we have obtained in this Unit.

5.0 Conclusion

Gradually, you are beginning to understand what the concept of pollution, particularly air pollution is. What pollutants are and are not. It is like saying salt has changed its value when it is too much in food. Yes just like that! Next lecture unit will bring us to more important session, so letôs go.

6.0 Tutor Mark Questions

a. Mention 2 differences between air pollution and air pollutants
b. Mention 4 chemicals and describe their roles in the atmosphere

7.0 References/Further Reading

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UNIT 3: CLASSIFICATION AND SOURCES OF AIR POLLUTANTS

CONTENT

1.0 Introduction

In the previous Unit, a pollutant was defined and the broad types given. Some examples of the gases (chemical) that later become pollutants were also highlighted. This unit is a step higher. It discusses the sources of specific air pollutants. Please endeavour to read along; you only may need to pause after the brief discussion on each pollutant, and ask yourself, what further brief can I hold for this explanation? Think specifically of how their emissions from these sources could be minimized. Can they be entirely stopped? What is the implication of this on manôs development?

2.0 Objectives

The specific objectives of this Unit are:

a. Mention some specific air pollutants and describe the sources air pollutants; and
b. Classify the air pollutants into natural or man made

3.0 Main Content

3.1 Classes of Air pollutants

There is no hard and fast rule to the classification of pollutants. Acceptable classes for this lecture note are as categorized as described below:

(a) According to chemical composition: the following classes are identified. Their names have been given according to the prominent chemical compounds they contain:

i. Sulphur-containing compounds

ii. Nitrogen ï containing compounds

iii. Carbon-containing compounds

iv. Halogen-containing compounds

v. Toxic substances

vi. Radiative compounds

(b) According to physical state: the pollutants are classified as

i. Gaseous

ii. Liquid (aqueous)

iii. Solid

(c) According to the manner in which they reach the atmosphere

i. Primary pollutants (those emitted directly from the sources)

ii. Secondary pollutants (those formed in the atmosphere by chemical interactions among primary pollutants and normal atmospheric conditions

(d) According to the space scales of their effects

i. Local (or indoor)

ii. Regional

iii. Global

(e) Criteria air pollutants

There are six major pollutants defined by EPA (Environmental Protection Agency of the United States of America) for which ambient air standards have been set to protect human health and welfare.

i. Ozone, O_3

ii. Carbon monoxide, CO

iii. Sulphur dioxide, SO_2

iv. Nitrogen oxides, NO_x

v. Lead, Pb

vi. Particulates, PM10

3.2 Sources of Air Pollution

Basically, air pollution can result from both natural and man-made (anthropogenic) sources.

i. **Natural Sources:** These include volcanic eruption releasing poisonous gases, forest fire, natural organic and inorganic decays or vegetation decay, pollen scattering, deflation of sands and dust, sea salt particles being blown up from the surface of the sea by winds, extraterrestrial bodies, cosmic dust, and comets.

ii. **Man made (anthropogenic) sources:** The major anthropogenic sources include but not limited to substances emitted due to the burning of fossil fuels in engines, gasses and particulate matter created in the production process (industrial and agricultural), suspended particulate matter and chemical substances created in the process of waste disposal and even war. Some anthropogenic sources are briefly discussed.

a. Increased in human population and activities: the increase in population created several serious problems including the worsening of the conditions of the environment. An increase in population leads to the emission of green house gases and global warming. This in turn cause rise in sea level; and prospects of reduced food production. An increase in population also contributes to loss of forest and loss in wildlife species.

b. Indiscriminate cutting of plants, trees and clearing of the jungles and forests i.e. deforestation by man for his own needs has disturbed the balance of carbon dioxide and oxygen in nature.

c. Burning: The conventional sources of energy are wood, coal and fossil fuel. A large percentage of the energy we use in our homes and factories is generated from these sources. Burning of the

d. automobile exhausts: are responsible for a high percentage of total air pollution. Automobiles release huge amount of poisonous gases such as carbon monoxide, leaded gas and particulate lead as a result of incomplete combustion of petrol and diesel which react in the presence of other gases to form smog in the atmosphere which are toxic to nature. Examples of air pollutants include sulphur dioxide (SO_2), Nitrogen Dioxide (NO_2) suspended particulate matter, Carbon Monoxide (CO), photochemical oxidants (OX), Non-Methane Hydrocarbon Species (NMHC).

e. Industrial and human development activities: some gaseous air pollutants other than those mentioned above are nitric acid, gaseous nitric acid, PAN, gaseous fluorine, and hydrogen chloride. Other offensive odorous substances like ammonia, hydrogen sulphide, methyl sulphide, trimethylamine, dimethyl sulphide, aldehyde, and styrene are also considered to be gaseous air pollutants. In addition to suspended particulate matter, dust fall is also considered to be particulate air pollutant. It is the volume of dust fall is also considered to be particulate fall which falls in units of area. Some natural sources are soil which is scattered from the ground, volcanic emissions, seal salt particles, and biological sources like hydrocarbon substances which have been particularized in the atmosphere. Artifical sources include substances which have been emitted in factory production processes (including combustion) automobile emissions, substances which blown up off roads by traffic, and substances from the incineration of waste materials.

3.2.1 Specific sources of major air pollutants

In this section, a number of major pollutants will be discussed with their specific effects. Please note that we will not have only a pollutant scenario, instead what normally exist is that one or more pollutants become prominent. Examples of major pollutant as described below:

Ozone (O_3)

Characteristics of ozone as a pollutant

At ground level, ozone is a hazard (ôbadô ozone). It is a major constituent of photochemical smog. However, in the stratosphere, it serves to absorb some of the potentially harmful UV radiation from the sun, which is believed to cause skin cancer, among other things (ógoodô ozone).

Sources: ozone is not emitted into the atmosphere; ozone is formed from the ozone precursors, VOCs, and nitrogen oxides.

Major sulphur – containing compounds

Sulphur dioxide, SO_2: This is a colourless gas with a sharp odour, primary pollutant, has anthropogenic (man-made) and natural sources. Sulphur is present in many fuels (e.g. coal, crude oils) over a wide range of concentrations. Combustion causes its oxidation to sulphur dioxide.

Anthropogenic sources: industries burning sulphur-containing fossil fuels, ore smelters, oil refineries

Natural sources: marine plankton, sea water, bacteria, plants, volcanic eruption.

Major nitrogen-containing compounds

Nitrogen, N_2, is a dominant gas of the atmosphere about 78% by volume, NO_x stands for an indeterminate mixture of nitric oxide, NO, and nitrogen dioxide , NO_2 Nitrogen oxides, NO_x, are formed mainly from N_2 and O_2 during high-temperature combustion of fuel in cars.

Anthropogenic sources: motor vehicles, biomass burning.

Natural sources: bacteria, lighting, biomass burning

Major carbon-containing compounds

Carbon monoxide, CO, is a colorless odourless flammable gas, major pollutant of an urban air, produced from incomplete combustion. Note that CO is also produced by atmosphere oxidation of methane gas and other hydrocarbons.

Anthropogenic sources: petrol engine motor cars, cigarette smoke and biomass burning

Natural sources: biomass burning

Carbon dioxide, CO_2, is a key greenhouse gas. Principal sources include fossil fuel combustion, deforestation, cement production.

Hydrocarbons and volatile organic carbons (VOCs):

These are organic gases are those that contain both hydrogen and carbon, but may also contain other atoms; hydrocarbons (HCs) are organic gases that contain only hydrogen and carbon. Volatile organic compounds (VOCs) are non-methane hydrocarcons (NMHC) and oxygenated hydrocarbons (which are hydrocarbons plus oxygenated functional groups) Methane, CH_4, is the most abundant hydrocarbon in the atmosphere, found in exhaust gas from automobiles, biomass burning; agriculture activities (e.g., rice paddies).

Anthropogenic sources: indoor sources (e.g. formaldehyde emission), fossil fuel combustion, evaporation of gasoline (e.g. petroleum refineries; during fueling of cars),

Natural sources: HCs produced from decomposition of organic matter; emitted by certain types of plains (e.g. pine trees, creosote bushes)

Major halogen-containing compounds

Chlorofluorocarbons, CFCs, are artificial gases, used as the coolants in refrigerators and air conditioners; they are neither toxic nor flammable. The most abundant CFCs are CFC-11 (or $CFC1_3$), and CFC-12 (or CF_2Cl_2). CFCs are artificial halocarbons, therefore they are not biodegradable. CFCs are not water-soluble; therefore they are not washed from the atmosphere by rain. In the stratosphere, UV radiation destroys CFCs breaking them down to a few chemicals (including atomic chlorine and atomic bromine which efficiently destroy ozone).

Metals as the pollutants

Metal (such as lead, mercury, cadmium, chromium, nickel) found as impurities in fuels.

Anthropogenic sources: emitted by metal mining and processing facilities; motor vehicle. Lead is a very useful metal, has been mined for thousand of years

Particulate matters (aerosols) are solid or aqueous particles composed of one or several chemicals and small enough to remain suspended in the air (discussed in several lectures).

Example: dust, soot, smoke, sulfates, nitrates, asbestos, pesticides, bioaerosols (e.g. pollen, spores, bacterial cells, fragments of insects, etc). PM (10) are particles with diameter < 10 micrometers (μm)

Anthropogenic sources: various (biomass burning, gas to particle conversion; industrial processes; agricultureôs activities)

Natural sources: various (sea-salt, dust storm, biomass burning, volcanic debris, gas to particles conversion)

4.0 Summary

The purpose of this unit is to teach you the sources of air pollutants. Specific examples of these have also been given. Classifications of the pollutants have been made on a number of factors; the physical state, dominating compounds, etc notwithstanding, to categories have consistently appeared ; whether the sources are man-made (or anthropogenic) or natural. Specific sources of the pollutants have also been identified, especially based on the constituents of the chemical compounds. The roles of volcanic emissions and anthropogenic activities including burning, automobiles, industrial emissions, population growth and deforestation have also been identified.

5.0 Conclusion

Sources of air pollution are many but they can be grossly classified as natural and anthropogenic sources. This however does not mean that there is a physical boundary between them. Air pollution is a trans-boundary problem, and perhaps requires trans-national involvement in combating it. But before we start thinking of how do we curb this problem, the next unit emphasizes the effects of air population. Before that lets assess what you have learnt in this Unit with the following questions.

6.0 Tutor Marked Questions

a. mention three ways of categorizing air pollutants, and classes under each category
b. describe 5 sources of air pollutants

7.0 References/Further Reading

Heinsohn, R. J. and kabel, L. K. (1999), Sources and Control of Air Pollution, Prentice-Hall International , UK

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UNIT 4: EFFECTS OF AIR POLLUTIONS

Contents

1.0 Introduction

Pollution of the environment is one of the most horrible ecological crises the world is subjected today. The environment (air, land or soil and water) was in the past pure, virgin, undistributed, uncontaminated and basically most hospitable fir living organisms but the situation is just the reverse today. Today, the environment has become foul, contaminated, undesirable and therefore, harmful for the health of living organisms, including man. The previous units have informed us on the definition and characterization of the nature and the sources of air pollutants. This section informs us the effect of air pollutants on the environment. Please read along.

2.0 The objectives of this Unit is to

a. describe the effects of pollution on the atmospheric processes
b. describe the effects of pollution on manôs health
c. describe the effects of pollution on manôs environment

3.0 Main Content

3.1 Effects on weather, climate and atmospheric processes

In general, air pollution is responsible for 2 main global problems:

i. contamination of the upper atmosphere

ii. alteration of weather and climate

Some of the specific effects of pollution on the atmosphere are highlighted below:

a. Pollution affect local weather condition, as in the well the creation of a phenomenon known as ñHeat Islandò around cities. This is caused when heat emissions from many anthropogenic sources add to the warming of the built environment. This warming effect that results from this phenomenon could affect, significantly, the comfort and the liveability of the urban people. For instance, over 10,000 people died of heat wave (a consequence of heat island) in France in 2003 (Samuels, 2004).

b. The distribution and abundance of particulate matters is responsible for local rainfall patterns and hence there is a significance increase in precipitation in and around cities, and is due to air pollution. Air pollution causes weather to change on a continental or global basis.

c. Many gaseous pollutants and fine aerosols reach the upper atmosphere, where they have on the penetration and absorption of sunlight. According to modern environmentalists, increasing particulate mater pollution may reduce the amount of sunlight reaching the surface of the earth thereby lowering solar radiation energy at the earthôs surface.

3.2. Effect on humans health

Respiratory system and diseases

The first target organs attacked by air pollutants are respiratory system. Considering the respiratory system of humans, from the nasal cavity to near the bronchi, which constitute the passage of air, mucus covers the mucous epithelium. The airway of trachea and the bronchi are provided with cilia to eliminate foreign substances. Also, there are alveolar macrophages of phagocyte in the alveolar of the lungs exchanging carbonic dioxide for oxygen. Fig 4.1. shows the tendency of the atmospheric pollution to affect man.

Fig. 4.1 Man's respiratory system as it is affected by air pollution

Of the air pollutants inhaled, the larger particulate matters are caught in the nasal cavity. However, so-called suspended particulate matters, measuring 10μm or less in diameter pass through the nasal cavity to reach the trachea and/or the alveolar. Of the gaseous substances, sulphur dioxide, which is soluble in water, is absorbed mainly in the upper airway, causing chronic bronchitis or asthma. On the other hand, ozone, nitrogen oxides and other insoluble gaseous substances advance deep in the lungs, causing asthma or chronic bronchitis or possibly pulmonary emphysema. Also, carbon monoxide, when coming into contact with haemoglobin contained in the blood in alveolar, disturbs transportation of oxygen by the blood because the substance combines with haemoglobin more easily than oxygen.

In the case where the air severely polluted, aged persons and patients with certain chronic base disease in particular are in danger of excess death by suffering from acute bronchitis. In many cases, however, air pollution causes chronic respiratory diseases especially asthma, chronic bronchitis and lung emphysema. These respiratory diseases are known generally as chronic obstructive pulmonary diseases (COPD). Characteristics of these diseases as revealed by the pulmonary function check include smaller values for the forced expiratory volume percentage

in one second (the percentage of their whole expiration the patients can put in one second when they breathe out as fast as they can) and lower values for the maximum peak flow, while the vital lung capacities of the patients remain normal. Another disease that can be caused by air pollution is lung cancer. It should however be known that the causes of these diseases are not limited to air pollution. The figure below shows that asthma disease has increased with time at different category of ages.

Asthma Prevalence by Age

United States, 1980 ï 1994

Effects on senses (sense of smell)

Humans use their five senses of sight, hearing, smell, touch and taste as a mean of acquiring information from the outside world. The sense of smell works to identify the nature of odours and, along with taste, may be called a chemical sense. Smell

possesses functions that only respond to a limited number of chemical substances (those substances with odours). Humans mainly rely on their senses of sight and hearing to live, although sight and hearing are well developed, smell is, by comparison, a somewhat primitive sense. Odours such as that of rotting food and of burned substances aim to provide advance warnings of impending danger. On the other hand, on the basis of helping us to lead our individual lifestyles, such fragrances can be seen in perfume, cosmetics, flavours, and so forth are part of a sense essential for us to lead fulfilled lives, and if we were to consider life without the sense of smell, we immediately begin to realize just how important a sense it is.

Airborne odours enter the nasal cavity along with inhaled air, and arrive at olfactory membrane in the roof of the cavity by passing along the nasal airway, where they dissolve into the mucous olfactory membrane. The olfactory membrane contains olfactory glands (Bowmanôs glad) centred on olfactory cells, which are sense receptor cells. The olfactory glands hairs extend from the length of the olfactory cells through the mucous, and the tip of the cells (the olfactory smell vesicle) also protrudes into the mucous membrane. Odours molecules that enter the mucous collide with both the olfactory glands hairs and olfactory small vesicle, and excite the cell membrane thereby transmitting as impulse (an electrical signal) to the olfactory cells. The olfactory nerve, which protrudes, from the cells, enters the olfactory tube, which is the primary axis of the direct sense of smell. Moreover, a stimulus is transmitted to the cerebral cortex, where the nature of the odour is identified.

Effect on vegetation

In terms of the damage to plants caused by air pollution, forests could be damaged and agricultural area recording poor growth and yield. This could be caused by the sulphur dioxide (SO_2) and hydrogen fluoride (HF) from stationary sources. Plant damage could also result from mobile sources including automobiles.

Effects on material and cultural properties

The effects of air pollution are not only on peopleôs health and living things such as plants, but also extend to man-made items such as materials like metals and cultural properties. To recognize and investigate the effects of air pollution on materials and cultural properties is to evaluate the economic loss from the air pollution and at the same time improve the safe maintenance of public assets (see

Fig. 4.3. as example). Furthermore, we must identify the long term effect on cultural properties, which are assets of mankind but cannot have an economic value placed on them, and improve measures to preserve them. Because of this, each region and each individual country must investigate and identify the effect of air pollution on the materials and cultural properties.

Fig 4.3: Bleaching of this stone image was a result of air pollution

Visibility degradation

The light from the sum deteriorates its being absorbed and scattered due to aerosols; absorption by air pollutants and water vapour; scattering by airborne particles, among others. The main cause of visibility degradation due to air pollution are aerosol and gasses in the atmosphere, but the visibility conditions can differ greatly due to atmospheric condition such as humidity; the optical characteristics of the target; and the strength and distribution of the light at the time in question. When air pollution is sever, the atmosphere appears to be coloured. But the colour can vary depending on the type of pollution. Air pollution appears black when it is due to soot from the burning of fossil fuels, but has a whitish hue when it is due to photochemical pollution (Fig. 4.4)

Fig. 4.4: A city affected by atmospheric pollution

3.2. Specific Effects of Air Pollutants

a. Ozone

i. diverse effects on human health

ii. ecological effects: damage vegetable and trees

b. SO_2

i. at relatively high concentration SO_2 causes severe respiratory problems.

ii. Sulphur dioxide is an acid precursor, which is a source of acid rain produced when SO_2 combines with water droplets to form sulphur acid, H_2SO_4

iii. Sulphur dioxide is a precursor of sulphur particulates (sulphur) which affect the radiation balance of the atmosphere and can cause global cooling.

c. NO_x

i. causes the reddish brown haze in city air, which contributes to heart and lung problems and may be carcinogenic

ii. NO_x is an acid precursor, which is a source of acid rain produced when nitrogen oxides combine with water to produce nitric acid, HNO_3, and other acids

iii. Nitrogen oxides are the precursors of nitrate particulates (nitrates) which affect the radiation balance of the atmosphere and can contribute to global cooling

iv. Nitrogen oxides are major contributors to the formation of ground level ôbadô ozone.

d. CO effect:

i. CO is highly poisonous to humans and most animals: when inhaled, CO reduces the ability of blood haemoglobin to attach oxygen

e. CH_4

i. some HCs are indoor pollutants

ii. some HCs and VOCs contribute to ozone-containing smog

f. CFCs effects:

i. they are the key greenhouse compounds

ii. they lead to reduction of stratospheric ñgoodò ozone

g. Particulate matters (aerosols)

i. diverse health effects (e.g. harmful to human respiratory system)

ii. contribute to urban haze, cause visibility reduction

iii. play a key role in the earthôs radiative budget and global change

4.0 Summary

Different effects of air pollution on man and his environment has been discussed; air pollution affects our health, causing one health problem or the other. It also affects vegetation and impairs visibility into the distance. This may cause accidents in nay of the means of transportation. Many of these effects have the summarized here.

5.0 Conclusion

This Unit should also not pose any difficulty to you as it has only discussed what you are familiar with. Those of us that are based in Lagos come across this almost everyday. Outside Lagos may not be different; there is pollution everywhere and its affect attest to this. Besides, have you gained or learnt anything? If yes letôs see how it goes if you attempt the following g questions:

6.0 Tutor Marked Questions

a. mention 4 aspects of manôs life that could be affected by air pollution

b. describe the effect of air pollution of the vegetation

7.0 References/Further Reading

Makinde R., (2000) How to make Nigerian cities liveable. The Guardian, vol. 17, No. 7953, Gurdian Newspapers Limited, Isolo, Lagos.

Godish, T. (2004) Air Quality, 4th Edition, CRC Press, London

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UNIT 5: MITIGATION AND REMEDIATION MEASURES TO POLLUTION IN NIGERIA

CONTENTS

1.0 Introduction

Historical examination of laws on Nigerian environment before 1969 reveals a startling absence of any form of statutory regulations aimed at protecting the environment from industrial pollution. However, following the duping of toxic waste in Koko, a seaport in Delta State, in 1988, the government swung into action to deal effectively with the problems of environmental degradation. Since then efforts have been geared towards sustaining the environment.

2.0 Objectives

3.0 Main Content

3.1 Briefs on Nigeria's Environmental Policy and Institutional Framework

One of the first steps taken was to promulgate the Harmful Waste (Special Criminal Provisions, etc), Decree 42 in November 1988. The decree prohibits the purchase, sale, importation, transmit, transportation, and storage of harmful wastes in the country. Under the decree, the immunity from prosecution conferred on certain persons under the diplomatic immunity and privileges Act 1962 was removed. The decree prescribes life imprisonment for those who contravene its provision. This legal sanction was followed a month later by Decree No. 58 of 30th

December, 1988 which established a body known as the Federal Environmental Protection Agency (FEPA).

The Decree also provides for the national environmental standards on water quality, efficient limitations, air quality and atmospheric protection, noise control, discharge of hazardous substances and released offences. Within the context of the Decree, FEPA is expected to cooperate with the Ministry of Petroleum Resources (Petroleum Resources Department) for the removal of oil0related pollutantsô discharged into the Nigerian environment. The Decree also empowered FEPA to inspect, search, seize and arrest offenders. The Decree also provides for general penalties for individuals as well as for companies and firms found liable. Whereas an individual on conviction is liable to a fine not exceeding ₦20,000.00 or to imprisonment for a term not exceeding 2 years (or both), a corporate body found liable would pay a fine of not exceeding N500,000.00 and compensation commensurate with the breach thereof and restoration of the polluted area to an acceptable level as approved by the agency.

The functions of FEPA as spelt out by the decree, include:

i. the responsibility for the protection and development of the environment in general, and environmental technology, including initiation of policy in relation to environmental research an technology

ii. advising the Federal Government on national environmental policies and priorities and/on scientific and technological activities affecting the environment

iii. preparing periodic master plans for the development of environmental science and technology and advising the Federal Government on the financial requirements for the implementation of such plans;

iv. carrying out such other activities as are necessary or expedient for the full discharge of the functions of the agency

For effective implementation of the above functions, Decree 58 of 1988 also allows FEPA to:

i. Make grants to suitable authorities and bodies with similar functions for demonstration and for such other purposes as may be determined appropriate to further the purposes and objectives of FEPA

ii. Collect and make available, through publications and other appropriate means and in cooperation with public or private organization, basic scientific data and other information pertaining to pollution and environmental protection matters:

iii. Enter into contracts with public or private organizations and individuals to develop, utilize, coordinate and share environmental monitoring programmes, research efforts, basic data on chemical physical and biological effects of various activities on the environment and other environmentally related activities as appropriate

iv. Establish such procedures for industrial or agricultural activities in order to minimize damage to the environment from such activities

v. Maintain a programme of technical assistance to bodies (public or private) concerning implementation of environmental criteria, guidelines, regulations and standard thereof

vi. Develop and promote such processes, methods, device and materials as may be useful or incidental in carrying out the purpose and provisions of the Decree.

3.2. Coordinating Bodies on Nigerian Environment

Nigeria through the Federal Environmental Protection Agency (FEPA) had achieved the following major milestone in environmental protection and conservation of natural resources: development of the National Policy on the Environment; establishment of a National Council on Environment (NCE); establishment of a National Advisory Committee (NAC) on Agenda 21; review of National Environmental Policy Guidelines and Standards; enactment of the Environmental Impact Assessment (EIA) Law; establishment of a National Energy Policy; and enactment of Nuclear Safety and Radiation Protection Legislation; implementation of the National Agenda 1; and the initial development of the VISION 2010 strategy.

The National Council on Environment, established in 1990, provides a forum for consultation and harmonization of environmental management matters throughout the federation. Membership includes all the Federation as well as the Secretaries to the State Governments. Some of the achievements include the harmonization of

environmental protection institution throughout the Federation and the creation of State Environmental Protection Agencies in all the States of the Federation.

Following the Regional Workshop on the Implementation of Agenda 21 in Africa held in Abuja, Nigeria, the Federal Government established a National Advisory Committee on the Implementation of Agenda 21 in 1993. the Committee is made up of professionals from relevant private sector and government organizations, the academic community, Non-Governmental Organisation (NGOs), and Community Based Organisations (CBOs). The Committee advises the Federal Government of Nigeria on sustainable development issues and strategies for implementing the provision of Agenda 21.

3.3 Legislation and Regulations

As part of Government efforts towards integrating environmental concerns into development, the guidelines and standards approved prior to the United Nations Conference on Environment and Development (UNCED) were reviewed through Decree 59 in 1992. Apart from expanding the mandates of FEPA, the Decree legalized the proposed Guidelines and Standards for Environmental Pollution Control, the Regulations on Effluent Limitations, Pollution Abatement in Industries, and the Regulations for the Management of Solid and Hazardous Wastes.

The EIA Law was enacted by the Federal Government in 1992 as a tool for integrating environmental concerns into all major activities throughout the country. Procedural and Sectoral Guidelines for Agriculture and Rural Development, Oil and Gas, Infrastructural Manufacturing, and Mining activities in the country have also been put in place. The Nuclear Safety and Radiation Protection Legislation was enacted in 1995, which sets standards and procedures for the safe use of nuclear radiation.

3.4 Strategies and Policies on Nigerian Environment

The National Policy on the Environment was launched by the Government on 27 November, 1989. It contains specific guidelines for achieving sustainable development in fourteen vital sectors of the nationôs economy, namely: Human population; Land Use and Soil Conservation; Water Resources Management; Forestry, Wildlife and Protected Natural Areas; Marine and Coastal Area

Resources; Sanitation and Waste Management; Toxic and Hazardous Substances; Mining and Mineral Resources; Agricultural Chemicals; Energy Production; Air Pollution; Noise in the Working Environment; Settlement; Recreational Space, Green Belts, Monuments, and Cultural Property.

The Government through the Ministry of Science and Technology, has prepared a National Energy Policy that places emphasis on the exploitation of Nigeriaôs renewable and alternative energy sources (wind, solar, and biomass), and provides guidelines for environmental protection in the exploitation of Nigeriaôs fossil energy sources. It will soon be enacted into law.

The Ministry of Petroleum Resources, through various Petroleum Acts and subsidiary legislation ensures that the petroleum industry carried out its activities safely and in an environmentally sound manner.

4.0 Summary

We have viewed the mitigation measures to pollution in this lecture series within the context of Nigeria. We have read about a number of statutory issues related to this. Before the toxic waste dump in Koko, Delta State, nothing was happening in Nigeria considering the need to ensure environmental sustenance, but thereafter Nigeria woke from slumber and instituted the Federal Environmental Protection Act in 1988. This was followed by a number of decrees and other statutory protocols that have been discussed in this lecture. The role of the instituted Agency (FEPA) was clearly spelt out, likewise the following National Policy on the Environment. Other statutory plans have also been highlighted in this lecture.

5.0 Conclusion

Evidence from the discussion in this Unit has shown that Nigeria is aware of the implication of pollution to her environment. This is evident in the number of concerns, decrees and policies provided. It is noteworthy that the country now has a Ministry of Environment, and that concerned with the Niger Delta (a region that has been described as polluted by many concerned writers in and outside the country). What should bother us as students is the challenge that despite all these provisions and awareness, Nigeria environment (perhaps excluding Lagos now?) keeps fouling.

6.0 Tutor Marked Assignment

a. Mention 4 functions of FEPA (now the Ministry of Environment) as spelt out by the Decree 58 of 1988

b. Mention 4 decrees, laws or policies that are directed toward environmental management in Nigeria

7.0 References/Further Reading

FEPA, (1991), *National Environmental Protection (Effluent Limitation) Regulations* (S.1.8), FEPA, FGPL, Lagos, Nigeria

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UNIT 6: INTRODUCTION TO NOISE POLLUTION: SOUND AND NOISE

CONTENTS

1.0 Introduction

In the previous five units of this lecture series, we have studied air pollution. Equally important but often ignored is noise pollution which will now form the focus of our discussion in the next few units. There is widespread and increasing excessive noise exposure everywhere, especially in developing countries. In Africa there are high noise expose levels in the formal (e.g. manufacturing, mining) and informal occupational sector (small industries such as vehicle repairing, metal-working, milling), as well as the non-occupational sector (urban environmental and leisure). Awareness of hazard amongst employers, employees and the public is however very low. In most developing countries, occupational noise and urban, environmental noise (especially traffic noise) are increasing risk factors for hearing impairment. Many of these countries often lack both effective legislation against noise and programme to prevent noise-induced hearing loss. Where these exist, they are often poorly enforced and implemented. Well if or not our dear country Nigeria belongs to this will refocus as we read on. Meanwhile, let us at this juncture understand what noise pollution is, and differentiate from other related concepts.

2.0 Objectives

By the end of this unit, you should be able to achieve the following

a. differentiate between sound and noise pollution

b. describe how sound/noise is measured

3.0 Main Content

3.1 Sound and Noise

Sound is derived from pressure waves in the air by the vibrations of solid objects, e.g. plucking a guitar string. Sound waves are compressional, longitudinal waves made by variations in pressure moving in the same direction.

Sound is characterized by frequency and wavelength, and travels at a velocity of 331m/s Different materials can transmit or absorb sound of different frequencies. Noise, on the other hand, is an incoherent sound that is perceived to be annoying due to its loudness and dissonance. Noise nuisances are subjective, some people are more sensitive or find particular things worse than others.

When sound waves reach the ear, the structures within vibrate but sudden forceful vibration (noise) can rupture the eardrum. If the intensify of any sound is great, then human ears may be injured due to damage to the anatomical structures of the ear. Hearing loss usually, however, usually occurs slowly over a long period of time. The figure below shows the structure of a manôs air. The ear drum can be damaged by noise.

Fig. 6.1. An ear

One of the most important distinguishing characteristics between sound and noise is loudness. Loudness is measured in decibels (dB). Loudness of a sound is dependent upon proximity to source of sound. No damage will be done to the ear if the sound level is below 80 dB but steady exposure to sound higher than 80 dB can have negative long term effects on hearing.

The word ñnoiseò comes from the Latin word ñnoxiaò meaning ñinjuryò or ñhurtò. Noise can also be defined as unwanted sound. Sound, which pleases the listeners, is music and that which causes pain and annoyance is noise. At times, what is music for some can be noise for others.

Typical measurements of activities involving sound are as given in table 6.1. Sound that is above 80dB is already noise.

Table 6.1.: Typical Noise Levels in the Environment

Activity	**Sound level**
Pain	120-130 dB
Aircraft taking off	110 dB
Loud Rock Music	100dB
Semi Truck (short term hazard)	90dB
Jack Hammer	80dB
Traffic (occupational limit)	70dB
Conversation	60dB
Background office noise	50dB
Quiet bedroom	10-20dB
Threshold of hearing	0dB

3.2 How is Sound Measured?

Noise is usually measured either by sound pressure or sound intensify.

Noise intensify is measured in decibel units. The decibel scale is logarithmic; each 10-decibel increase represents a tenfold increase in noise intensify. Human perception of loudness also conforms to a logarithmic scale; a 10-decibel increase is perceived as roughly a doubling of loudness.

Thus, 30-decibels is 10 times more intense than 20 decibels and sounds twice as loud; 40 decibels is 100 times more than 20 and sounds 4 times as loud; 80 decibels is 1 million times more intense than 20 and sounds 64 times as loud. Distance diminishes the effective decibel level reaching the ear. Thus, moderate auto traffic at a distance of 30 m rates about 50 decibels. To a driver with a car window open or a pedestrian on the sidewalk, the same traffic rates about 70 decibels; that is, it sounds 4 times louder. At a distance of 600m, the noise of a jet takeoff reaches about 110 decibels ï approximately the same as an automobile horn only 1m away.

For human noise response, the decibel scale is adjusted slightly to 8 compensate for slight aberrations in the way the human ear ñhearsò sound along the scale. This adjusted scale is known as the A weighted decibel scale, and the units of the scale are dBA. The Environmental Protection Agency (EPA, USA) has produced a table which describes how various decibel levels might sounds as follows:

Table 6.2 dBA Levels and Associated Sound

dBA	**dBA sound description**
0	Absolute silence
25	Very quiet room
35	Rural night time setting. No wind
55	Day time, busy roadway 0.5km away
70	Busy restaurant
85	Very busy public place, voice has to be raised to be heard
100	Disco or rock concert
120	Uncomfortably loud, conversation impossible
140	Noise causing pain in ears

4.0 Summary

In this study, we have learnt that sound is not synonymous to noise. While both are forms of energy that involves transfer of waves, sound in the pressure wave between 0 and 80 decibels. Noise on the other hand is an incoherent sound, normally above 80dB and capable of causing injury to the hearer. Noise could this be termed as a pollutant, and the type of pollution inherent in it called noise pollution. You have also learnt of the characteristics of sound and the different standards of measures that can be referred to as standards.

5.0 Conclusion

This is just an introductory unit. It is intended to introduce you to the concept of noise pollution. Once you know that noise is a pollutant. We should be able to think of its types or forms, causes and ways of curbing it. That is just the goal for the next few units. Please let us go on.

6.0 Tutor Marked Assignment

a. highlight 2 differences between sound and noise

b. mention 4 activities and the sound levels

7.0 References/Further Reading

Spence, D. (2003); Pollution, Noise Pollution & Toxic Torts.

Environmental Law Lecture 7 delivered at the Law Society. Earlsfort Centre, Dublin

http://www.dmoz.org/Society/Issues/Environment/Noise_Pollution//

http://www.wired.com/science/planetearth/magazine/10-06/st_thompson

http://en.wikipedia.org/wiki/lighting

UNIT 7: DEFINITION AND TYPES OF NOISE POLLUTION

CONTENTS

1.0 Introduction

Modern life has given rise to a new form of pollution, noise. Crowded cities and towns, mechanized means of transport, new devices of recreation and entertainment are polluting the atmosphere with their continuous noise. Noise, is no doubt a normal phenomenon of life and is derived to be one of the most effective alarm systems in manôs physical environment. However, it is continuously disturbing human peace and tranquility. Gradually, noise has become an important environmental pollutant and a threat to the quality of manôs atmosphere.

2.0 Objectives

By the end of this unit, you should be able to achieve the following

a. define noise pollution; and

b. describe the types of noise pollution

3.0 Main Content

3.1 What is Noise Pollution?

According to Encyclopedia Britannica: In acoustic, noise is define as any undesired sound.

In chambers 21st Century Dictionary the definition of noise has undergone a change. Noise pollution stands carved out as phrase separately from noise. The two are defined as under.

Noise + a sound, a harsh disagreeable sound, or such sound; a din pollution ï an excessive or annoying degree of noise in a particular area, e.g. from traffic or aero plane engines.

Noise pollution is an act in which displeasing human ï or machine created sound that disrupts the activity of balance of human or animal life is introduced to the environment. It can equally be described as an unwanted sound dumped into the environment without regard to the adverse effects it may have.

The following facts are important about noise pollution in recent time:

i. noise from recreational vehicles has become a serious problem in rural areas

ii. noise pollution, usually called environmental noise in technical venues, is displeasing human or machine created sound that disrupts the environment

iii. the dominant form of noise pollution is from transportation sources

3.2 Types of Noise Pollution

i. Road Traffic Noise

In the city, the main sources of traffic noise are the motors and exhaust system of autos, smaller trucks, buses, and motorcycles. This type of noise can be augmented by narrow streets and tall buildings, which produce a canyon in which traffic noise reverberates

ii. Air Craft Noise

Nowadays, the problem of low flying military aircraft has added a new dimension to community annoyance, as the nation seeks to improve its aircraft operations over national parks, wilderness areas, and other areas previously unaffected by aircraft noise has claimed national attention over recent years.

iii. Noise from railroads

The noise from locomobile engines, horns and whistles, and switching and shunting operation in rail yards can impact neighbouring communities and railroad workers. For example, rail car retarders can produce a high frequency, high level screech that can reach peal levels of 120 dB at a distance of 100 feet, which translates to levels as high as 138, or 140 dB at the railroad workerôs ear.

iv. Construction Noise

The noise from the construction of highways, city streets, and buildings is a major contributor to the urban scene. Construction noise sources include pneumatic hammers, air compressors, bulldozers, loaders, dump trucks (and their back-up signals), and pavement breakers.

v. Noise in Industry

Although industrial noise is one of the less prevalent community noise problems, neighbours of noisy manufacturing plants can be disturbed by sources such as fans, motors, and compressors mounted on the outside of buildings interior noise can also be transmitted to the community through open windows and doors, and even through building walls. These interior noise sources have significant impacts on industrial workers, among whom noise-induced hearing loss is unfortunately common.

vi. Noise in building

Apartment dwellers are often annoyed by noise in their homes, especially when the building is not well designed and constructed. In this case, internal building noise from plumbing, boilers, generators, air conditioners,

and fans can be audible and annoying. Improperly insulated walls and ceilings can reveal the sound of amplified music, voices, footfalls and noisy activities from neighbouring units. External noise from emergency vehicles, traffic, refuse collection, and other city noises can be a problem for urban residents, especially when windows are open or insufficiently glazed.

A loudspeaker: source of noise

vi. Noise from Consumer products

Certain household equipment, such as vacuum cleaners and some kitchen appliances have been and continue to be noisemakers, although their contribution to the daily noise dose is usually not very large.

4.0 Summary

In this study, we have learnt basically the definition of noise pollution and the different types of the pollution. Please note that the types have been discussed with the sources, as its classification is based on it.

5.0 Conclusion

This unit has described noise as an environmental pollution which is equally detrimental to the achievement of a harmonious environment. As trivial as noise may appear in our environment, its consequences is important. The next Unit prepares you for that.

6.0 Tutor Marked Questions

a. define noise pollution

b. describe 5 types of noise pollution

7.0 References/Further Reading

Spence, D (2003): Pollution, Noise Pollution & Toxic Torts. Environmental Law Lecture 7 delivered at the Law Society. Earlsfort Centre, Dublin

http://www.dmoz.org/Society/Issues/Environment/Noise_pollution//

http://www.wired.com/science/planetearth/magazine/16-06/st_thompson

UNIT 8: EFFECTS OF NOISE POLLUTION

CONTENTS

1.0 Introduction

As concluded in the previous unit, the effect of noise pollution is multifaceted and inter related. It could be as related to humans, animals and property. Subjected to 45 decibels of noise, the average person cannot sleep. At 120 decibels the ear registers pain, but hearing damage begins at a much lower level, about 85 decibels. The duration of the exposure is also important. There is evidence that among young city dwellers, hearing sensitivity is decreasing year by year because of exposure to noise, including excessively amplified music. This and others related effects will be reviewed in this Unit.

2.0 Objectives

By the end of this unit, you should be able to achieve the following

a. highlight the effects of noise pollution on man

b. enumerate the effects of noise pollution on other components of the environment

3.0 Main Content

3.1 Effects of Noise on Human Health

Noise health effects are both health and behavioural in nature

i. noise can damage physiological and psychological health

ii. noise pollution can cause annoyance and aggression, hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances, and other harmful effects

- stress and hypertension are the leading causes to health problems and tinnitus can lead to forgetfulness, severe depression and at times panic attacks

iii. chronic exposure to noise may cause noise induced hearing loss

iv. high noise levels can contribute to cardiovascular effects; exposure to moderately high levels during a single eight hour period causes a statistical rise in blood pressure of five to ten points and an increase in stress and vasoconstriction leading to the increased blood pressure noted above as well as to increased incidence of coronary artery disease.

v. Noise pollution is also a cause of annoyance

3.2 Effects of Noise on the Environment

i. Noise can also have a detrimental effect on animals by causing stress, increasing risk of mortality by changing the delicate balance in predator/prey detection and avoidance, and by interfering with their use of sounds in communication especially in relation to reproduction and in navigation. Acoustic overexposure can lead to temporary or permanent loss of hearing.

ii. An impact of noise on animal life is the reduction of usuable habitat that noisy areas may cause, which in the case of endangered species may be part of the path to extinction. One of the best known cases of damage caused by noise pollution is the death of certain species of beached whales, brought on by the loud sound of military sonar.

iii. Nose also makes species communicate louder, which is called Lombard vocal response. Scientists and researchers have conducted experiments that show whalesô song length is longer when submarine-detectors are on. If creatures donôt ñspeakò loud enough, their voice will be masked by anthropogenic sounds. These unheard voices might be warnings, finding of prey, or preparations of net-bubbling. When one species begins speaking louder, it will mask other speciesô voice, causing the whole ecosystem to eventually speak louder.

iv. Zebra finches become less faithful to their partners when exposed to traffic noise. This could alter a populationôs evolutionary trajectory by selecting traits, sapping resources normally devoted to other activities and thus lead to profound genetic and evolutionary consequences.

4.0 Summary

In this Unit, two main divisions of the effects have been described; these include the effects on man, and the environment, especially animals. These effects are direct and spontaneous, and are all negative. These range from moderate to severe effects, including

i. sleep interference;

ii. speech interference;

iii. hazard to hearing from long term exposure;

iv. hazard to hearing from short term exposure; and

v. acoustic trauma ï causes pain

5.0 Conclusion

This unit has described the effects of noise as an environmental pollution on man and animals. The next Unit will focused on one important effect, noise induced hearing problems in man

6.0 Tutor Marked Assignment

a. enumerate 5 effects of noise on man

b. enumerate 5 effects of noise on other components of the environment of man

7.0. References/Further Reading

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UNIT 9: NOISE INDUCED HEARING LOSS (NIHL)

CONTENTS

1.0 Introduction

At the end of the World Health Organizations Programme for the Prevention of Deafness and Hearing Impairment (1997)ôs meeting (WHO-PDH Informal Consultation, 28 ï 30 October 1997 in Geneva) it was revealed that there is widespread and increasing excessive noise exposure everywhere, especially in developing countries. The communiqué also revealed that Africa is prone to high noise exposure levels in the formal (e.g. manufacturing, mining) and informal occupational sector (small industries such as vehicle repairing, metal-working, milling), as well as the non-occupational sector (urban, environmental and leisure). Awareness of hazard amongst employers, employees and the public is however low as most countries in the region do not have effective programmes for prevention of NIHL. Hence, the inclusion of this Unit in this lecture series.

2.0 Objectives

By the end of this unit, you should be able to achieve the following

a. define NIHL

b. highlight the scope of the WHO (1997) on NIHL;

c. describe the pathogenesis of NIHL; and

d. enumerate the strategies for preventing NIHL

3.0 Main Content

3.1 What is NIHL?

The World Health Organisations Programme for the Prevention of Deafness and Hearing Impairment (1997) defined noise-induced hearing loss (NIHL) according to

i. noise exposure history: where there is material noise exposure, that is 100dB (NI) (noise immission) or 83 dBA Laeq, 40 (40 hours per week equivalent continous noise level) for a 50 year lifetime (equivalent exposure).

i. Audiometric criteria (these are applicable in addition to the noise history criteria).

   a. The impairment is predominantly sensorineural (air bone gap average at 1, 2 and 4kHz is less than 15dB; tympanometry could also be used to exclude middle ear disorders)

   b. The impairment is not unilateral (asymmetry average at 1, 2 and 4kHz less than 15dB).

   c. Additional indication of a noise attribution is found if the 0.5kHz threshold is less than 50dBHL, and if the difference between the high frequency thresholds average of 3, 4, 6 kHz and the low frequency threshold average of 0.5, 1, 2 kHz is equal or greater than 15 dB in those aged less than 50 years

3.2 The Scope of the NIHL Meeting

The scope of the meeting was to address the problem of noise-induced hearing loss as a significant cause of hearing impairment in all countries of the world, but especially in developing countries.

It focused on excessive social noise but also reviewed the effects of excessive occupational and environmental noise. The role of noise-induced hearing loss as a public health problem, and the possibilities for preventing hearing impairment by controlling excessive noise in the context of primary health care were considered.

The purpose of this meeting were as follows:

i. It reviewed current knowledge and opinion on the pathogenesis and epidemiology of noise ï induced hearing loss. Some indication of the size of the problem worldwide was also given by reports from the six WHO regions of the world, focusing particularly, but not exclusively, on the situation in various developing countries.

ii. The methods available for prevention and management of noise-induced hearing loss were examined from the individual, environmental and occupational standpoints. The effectiveness of these methods, including cost effectiveness, was addressed as well as their appropriateness for implementation in developing countries and integration into primary health care. The issue of detection and monitoring was covered in this section.

iii. The participants looked at the elements necessary for the development of a national plan for the prevention of noise-induced hearing loss, using examples from two developing countries and one developed country. This item was intended to address the particular needs and constraints in developing countries, such as the lack of resources for providing individual rehabilitation, or for enforcing legislation of implementing hearing conservation programmes

iv. The meeting determined the principal immediate and longer term needs in this field, especially with regard to data collection and research opportunities.

v. The outcomes of the meeting were o raise awareness amongst WHO member states of the size and nature of the problem of noise induced

hearing loss and the most appropriate and effective measures for its prevention.

vi. The recommendations will provide a framework for the development by the Programme for the Prevention of Deafness and Hearing Impairment of model guidelines for prevention of noise-induced hearing loss. These guidelines can then be adapted and customized by the various regions and by countries for incorporation into their national health programmes.

3.3. Pathogenesis of Noise-Induced Hearing Loss

This section attempts an explanation on NIHL; you can consult Fig 6.1 for the diagram of an ear to review some of the mentioned parts.

Excessive sound levels produce a hostile acoustic environment by masking wanted signals (e.g. speech or warning signals), and with chronic exposure, by a central blocking out of all auditory signals. In addition they damage the cochlea and thus produce noise-induced hearing loss. All these have a deleterious effect on education, communication, and the hearing of warning signals.

Hearing losses from many causes are additive, so that noise induced hearing loss has become a major cause of handicap in the ageing population, producing handicap sooner than would occur from age alone. There is also interaction between noise exposure and inhaled organic solvents such as toluene and certain autotoxin drug such as cisplatin and aminoglycoside antibiotics.

Sound damages the ear first at a frequency of about 4kHz (the ó4 kHz notchô) and one of the reasons for this is the acoustic resonance characteristics of the external ear. This hard walled tube, closed at one end, amplifies acoustic energy in the upper frequencies by about 10 decibels. In addition, individual variation in the acoustic transfer characteristics of the tube is a factor in the large variability in peopleôs susceptibility to noise.

Transduction of sound vibration to nerve impulses occurs in the cochlea. The hair cells in the organ of Corti may be damaged directly by noise, or indirectly by very high levels of continuous sound which causes vasoconstriction of the vessels of the stria-vascularis in the cochlea blood supply. This renders the hair cells relatively anoxic and thus secondarily damaged.

The amount and type of direct hair cell damage depends on the intensify of the sound. Above a certain minimum of frequency an intensity, the outer hair cells show signs of metabolic exhaustion with drooping of the stereocilia. This correlates with the common phenomenon of temporary threshold shift (TTS), which recovers within a few hours. Higher sound levels damage the outer hair cell stereocilia further, including destruction of the inter-cilia bridges, and recovery takes longer. Even higher levels of sound lead to collapse of the stereocilia, and the hair cell are eventually phagocytosed.

Outer hair cells amplify the movement of the basilar membrane of the cochlea by contracting when stimulated by sound. This increases the stimulus delivered to the inner hair cells which transude the mechanical movement to trigger a nervous impulse in the afferent nerve endings of the 8th nerve. If the outer hair cells are not functioning, sensitivity of the inner hair cells in the basal coil of the cochlea are the most sensitive to hearing loss. Hair cells in the basal coil of the cochlea are the most sensitive to noise damage; they are responsible for transuding higher frequencies and this accounts for the high frequency hearing loss found in noise damage ears.

3.4 Reports from Africa

Noise Exposure

Exposure to noise causing noise induced hearing loss in African countries can be divide into the following categories:

a. Small Scale Industries (informal sector): the majority of Africanôs work in small scale industries such as motor vehicle repairers, carpenters, metal artisans and corn mills. These workers have repeated exposure to high noise levels

b. Formal Industrial sector

   i. Manufacturing: manufacturing factories in Africa that may cause exposure to high levels of noise include textile factories in Ghana, Kenya, Nigeria, South Africa, Swaziland, Tanzania and many other countries, and cocoa-processing factories such as in Ghana, Cote dôIvoire, Nigeria etc.

ii. Mining and quarrying industries can be found in Ghana, South Africa, Swaziland, Zimbabwe, etc and every country in Africa has construction workers

iii. Other professionals who are exposed to hazardous noise are the military, the police, fire fighters and aviation workers.

c. Sources of non-occupational noise

i. Recorded high volume music, church bands and leisure activities such as hunting re hazardous

ii. Exposure to noise from traffic during travel between home, work and school

iii. Exposure to noise from some home-based activities (e.g. use of noisy toys by children in some African homes).

3.5. Strategies for Prevention of NIHL

Considering the damaging effects of noise on hearing, it is necessary for governments in African countries to enact laws to protect those at risk and define the features of occupational noise exposure and hearing conservation programmes.

The primary motive for industrial noise control and related programmes is that of protecting the health of employees and reducing the likely legal liability of employers (where the laws exist) who may be held accountable for the impairments or disabilities incurred through employment.

The major social value underlying protection from workplace noise is that an employee should not have to risk injury to earn a living; another is that of avoiding deterioration of job performance because of reduced sensory ability. Countries such as Seychelles and Swaziland are attempting to make such laws very effective.

3.5.1 Occupational strategies

Hearing conservation programmes for occupational settings much include the following interactive components:

a. Noise surveys to determine the degree of hazardous noise exposure by surveying any area in which workers are likely to be exposed to hazardous noise (>85dBA). Level of hazard depends on noise intensify, duration of

exposure during a typical working day and overall exposure during working life.

b. Engineering and administrative controls are undertaken to reduce exposures to <90dBA, and include: design of equipment, its location and layout, selection of quieter machine, treatment of noisy rooms, administrative controls, proper maintenance and isolation of the worker from noise source.

c. Audiometric tests, by pre-employment and periodic follow0up testing by employers, to help determine employee effects; employee medical history and non-workplace noise exposure should be assessed.

d. Company sponsored education programmes to stress the importance of good hearing conservation practices on and off the job an inform employees about other factors or diseases that may affect their hearing.

e. Hearing protection devices to reduce the amount of sound reaching the ear. Employees having noisy hobbies, or with noisy second jobs, should be encouraged to use effective hearing protection during this noise exposure as well as at the work place.

f. All parties concerned ï government, employers, workers and factory inspectors ï should be involved in implementing noise control measures using the ôbottom-topô approach.

3.5.2 Non-occupational strategies

Hearing loss from non-occupational noise is common in African countries, but awareness of the hazards is low. Strategies in the non-occupational setting should include the following

a. Education programmes targeted towards children, young people, parents, hobby groups and professional in influential positions, such as teachers, physicians, audiologists, engineers, other health-care professionals, architects and legislators.

b. High visibility media campaigns to develop public awareness of the effects of noise on hearing and the means for self protection

c. Prevention of NIHL should be part of the health curricula in pre-university institutions in Africa.

d. Self-education materials for adults should be readily available

e. Assisting consumers in purchasing quieter devices

f. Legislation to control environmental noise and at certain spectator events

g. Training more audiologists, audiologist technicians and ENT surgeons

h. Assistance from NGOs to establish audiological facilities in developing countries

4.0 Summary

In this Unit, the perspective of noise-induced hearing loss has been considered. The approach is based on the communiqué of the WHO meeting on the phenomenon. The situation in Africa was reviewed because information about it in Nigeria is rather insignificant. Approaches for combating the problem were also discussed in the Unit; i.e. occupational and non-occupational strategies.

5.0 Conclusion

Exposure to excessive noise is the major avoidable cause of permanent hearing impairment worldwide. In a developed country, exposure to excessive noise is at least partially the cause in more than one-third of those in the population who have hearing impairment. In many countries, NIHL is the most prevalent irreversible industrial disease and noise is the biggest compensable occupational hazard. Furthermore, in developing countries, occupational noise and urban, environmental noise are increasing risk factors for hearing impairment. Exposure to excessive noise is also of concern because it is associated with distressing conditions such as tinnitus.

6.0 Tutor Marked Assignment

a. What is NIHL?

b. Highlight 5 strategies for the prevention of NIHL in Africa?

c. Express in your own view the position of Nigeria on NIHL and suggest the way forward.

7.0 References/Further Reading

World Health Organisation (1997) *Strategies for Prevention of Deafness and Hearing Impairment* Report of a WHO-PDH Informal Consultation, Geneva, 28 ï 30 October, 1997.

UNIT 10: PREVENTION AND MITIGATION OF NOISE POLLUTION

CONTENTS

1.0 Introduction

Once a problem has been identified, a god measure should exist to control it. Although the previous chapter addressed this in view of the noise induced hearing loss (NIHL), it is also necessary to highlight some specific measures that have been put in place in some areas to curb the impact of the pollution source seek its prevention. This of course could be foreign to us here in Nigeria, especially those of us that lice in noisy environment, where noises have become our friend, it is however significant that we observe this and perhaps seek solution to the problem. Hence this unit focuses on providing such awareness.

2.0 Objectives

By the end of this unit, you should be able to achieve the following

a. highlight some technological and legal measured aimed at preventing noise pollution

b. enumerate the steps to take to be protected from noise pollution

3.0 Main Content

Measures of preventing noise pollution can be viewed under two approaches: technology and legal. These are discussed below:

3.1 Technological approach

Technology to mitigate or remove noises from roads and aircrafts, other types of noises could effectively be controlled with the use of a strictly enforced legislation. Meanwhile, the view of technology approach can be applied as discussed below:

a. Road Traffic Noise

There are a variety of strategies for mitigating roadway noise including: use of noise barriers, limitation of vehicle speeds, alteration of roadway surface texture, limitation of heavy vehicles, use of traffic controls that smooth vehicle flow to reduce braking and acceleration, and tire design (see Fig. 10.1 for a comprehensive approach to this)

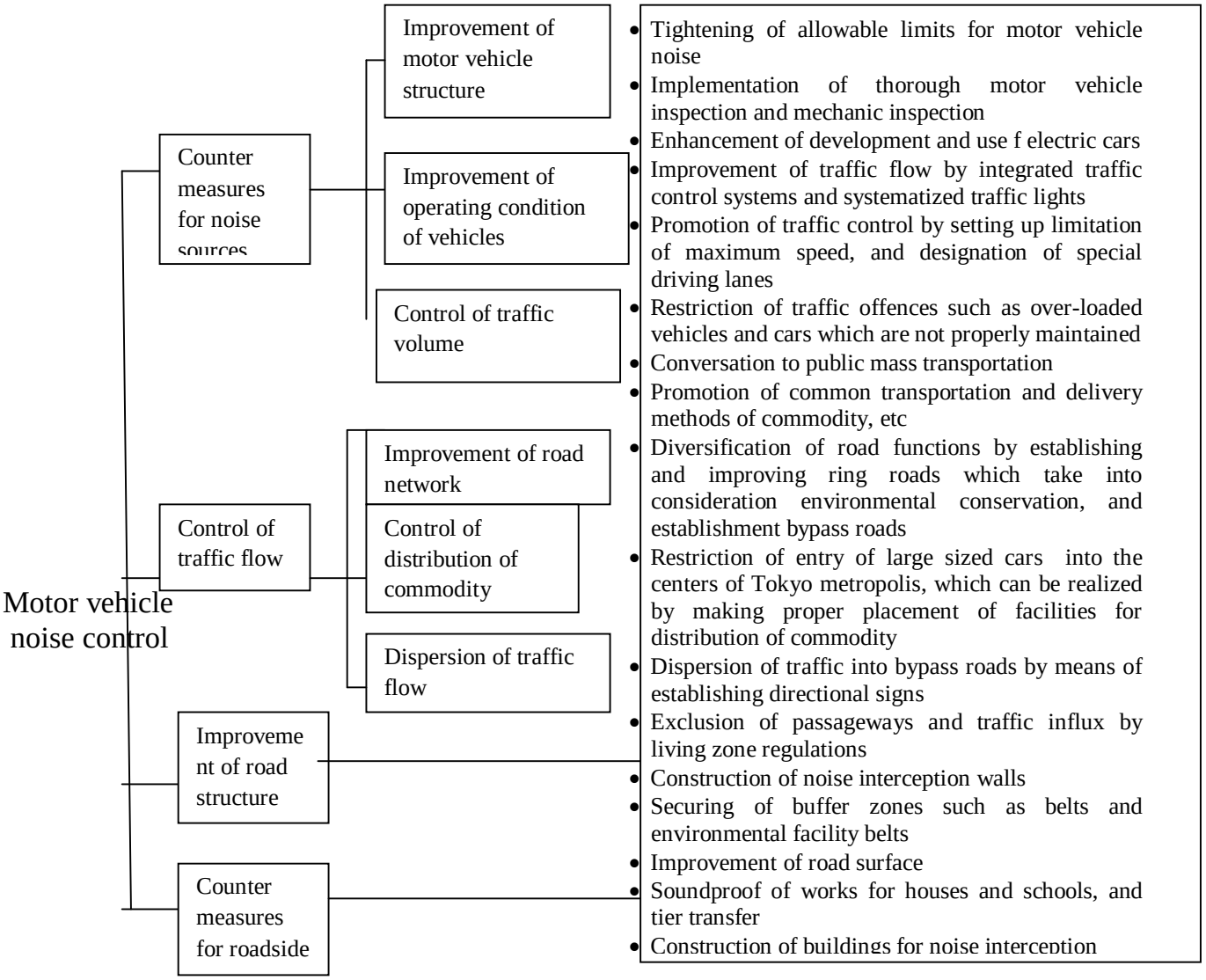

Fig. 10.1: Control Scheme for Motor Vehicle Noise Pollution

Other measures are

i. Promotion of evaluation of environmental impacts before establishment of new roads or reconstruction of existing roads

ii. Strengthening monitoring and surveillance

iii. Promotion of research and development of noise abatement technology and development of new traffic systems

iv. Activities to enlighten people how to make appropriate use of motor vehicles

v. Another measure is to control the total exhaust from automobile traffic

vi. Efforts should be made for the comprehensive and systematic promotion of the following measures:

- The readjustment of the cargo flow in which the truck traffic will be reduced by increasing material transportation efficiency, the readjustment of the passenger flow in which passenger car use will be reduced by improving public transportation systems,
- The construction of more bypass and beltway roads with consideration given to environmental conservation, improving traffic flow to disperse and smooth traffic flow by improving traffic control systems and intersection designs, and other specific measures

a. <u>Promoting the Corrective Measures</u>

The road traffic pollution problems are very closely tied in with the localities, and, in order to solve such problems, it is necessary to formulate effective measures fit for each district, depending on the local conditions and characteristics, with each State government playing the leading role by taking advantage, if necessary, of councils in which local agencies of the central government take part. There is also a need for the government to step up the measures the government should carry out under a system of close liaison and cooperation between ministries and agencies and also to support the measures which are implemented by local governments.

b. Air Craft noise

Aircraft noise can be reduced to some extent by design of quieter jet engines. This strategy has brought limited but noticeable reduction of urban sound levels in some developed countries. Reconsideration of operations, such as altering flight paths and time of day runway use, has demonstrated benefits for residential populations near airports. Specific activities are as shown in Fig. 10.2

3.2 Legal Approach

Many Environmental policies in developing countries up till now view noise as a ñnuisanceò rather than an environmental problem. In the United States there are federal standards for highway and aircraft noise; states and local governments typically have very specific statues on building codes, urban planning and roadway development. In Canada and the EU there are few national, provincial, or state laws that protect against noise. Well, we may need to find out if there is any of such in Nigeria (Assignment 10.1)

Noise laws and ordinances could vary widely among municipalities and indeed do not even exist in some cities. An ordinance may contain a general prohibition against making noise that is a nuisance, or it may set out specific guidelines for the levels of noise allowable at certain times of the day and for certain activities.

Most city ordinances prohibit sound above threshold intensify from trespassing over property line at night, especially between 10pm and6am. And during the day restrict it to a higher sound level; however, enforcement is uneven. Many municipalities do not follow up on complaints. Even where a municipality has an enforcement office, it may only be willing to issue warnings, since taking offenders to court is expensive.

Many conflicts over noise pollution are handled by negotiation between the emitter and the receiver. Escalation procedures vary by country, and may include action in conjunction with local authorities, in particular the police. Noise pollution often persists because only five to ten percent of people affected by noise will lodge a formal complaint. Many people are not aware of their legal right to quiet and do not know how o register a complaint.

3.3. Learning to be protected from Noise Pollution: there are few steps to achieve this; they are expressed below:

- always wear hearing protection when working around loud noises
- take breaks when working in noisy areas
- limit exposure to loud music
- have regular hearing tests for any loss of hearing

4.0 Summary

A problem that can be caused may be solved. All that is required is the awareness that it is a problem. In this unit, both the technological and legal approaches to preventing noise pollution have been discussed. It was shown in this Unit that traffic noise will require a great deal of technological improvement of the vehicle engine, the road, aircraft and airport in case of the airways. Others, neighbourhood noise, etc will be prevented if adequate legal frameworks is in place and enforceable. The Unit however revealed that Nigeria either does not have such framework in place or does not enforce it. It also showed that noise pollution should rather be viewed as an environmental problem rather than a nuisance because this has narrowed the concern for it. The unit has also briefly highlighted some steps for an individual to be protected from noise pollution.

5.0 Conclusion

This unit has described a number of mitigation measures for noise pollution. It is however interesting to place Nigeria within this context; how has the country fared with controlling noise pollution; what about the concurrencies in our cities; is there any appreciable framework, and how has this been enforced? Let the class have a discussion on this and let our ideas be summarized.

6.0 Tutor Marked Assignments

a. Enumerate 5 mitigation measures for traffic noise pollution

b. Highlight 4 steps to protect yourself from noise pollution

7.0 References/Further Reading

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