LECTURE NOTES

For Environmental Health Science Students

Air Pollution



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In collaboration with the Ethiopia Public Health Training Initiative, The Carter Center, the Ethiopia Ministry of Health, and the Ethiopia Ministry of Education

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PREFACE

Shortage of appropriate textbooks that could meet the need for training professionals on the nature and the magnitude of ambient and indoor air pollutions and their effects have been one of the outstanding problems in the existing higher health learning institutions in Ethiopia. Therefore, a well-developed teaching material to produce the required qualified health professionals, who are considered to shoulder the responsibility of preventing and controlling of air pollutions by creating awareness and entertaining some interventional measures among the communities, is obvious.

The present lecture note on "Air pollution" is therefore, prepared to be used as a teaching material to train mainly environmental health and other students of health category in Ethiopia. It is believed this teaching material plays a significant role to solve the critical shortage of reference books and text on the subject. The lecture note is designed to make the training somehow a practical application to the actual indoor and out door air pollutions in the country. It contains five chapters in which the major current out/ in-door air pollution problems with their suggested solutions are discussed. Each chapter is presented in simple language and is provided with learning objectives, body introduction,

journals, internet sources and other lecture manuscript are used to develop this lecture material.

We have also incorporated the useful ideas of different instructors of the course to standardize it to its present status, which the authors hope to further improve the draft through the consultations, pretest and revisions. It is also hoped that this lecture note will be of particular use not only for students of health category in colleges and universities, but to those graduates working in health care service institutions and environmental protection agencies.

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Table Contents

Preface	i
Acknowledgements	iii
Table of content	iv
List of Tables	viii
List of figures/boxes	ix
Abbreviation	Х
CHAPTER ONE: Introduction	1
1.1. Learning Objective	1
1.2. Introduction to the course	1
1.3. Historical Overview	8
1.4. Definition of terms and scale conversion	10
1.5. Energy Transfer	14

and Their Effects	46
3.1 Learning Objective	46
3.2 Introduction to the Chapter	46
3.3 Common condition to which air pollution exposu	re
may contribute	47
3.4 Types of Air Pollutants	49
3.4.1. Conventional Air Pollutants	49
3.4.2. Non Conventional Air Pollutants	62
3.5. Magnitude and source of ambient air pollution	78
3.6. Exercise quesi1rn.21(7dR)]Tz27r P800	19 (86 TD0005 Tc-T4 127.5()-1/MC0

CHAPTER THREE: Sources, Types of Air Pollutants

	5.6. Exercise question	106
CH	IAPTER SIX: Indoor Air Pollution	107
	6.1. Learning Objective	107
	6.2. Introduction to the Chapter	107
	6.3. Environmental tobacco smoke	109
	6.4. Radon gas	110
	6.5. Formaldehyde	113
	6.6. Asbestos	114
	6.7. Lead	114
	6.8. Carbon Monoxide	115
	6.9. Biological Contaminants	119
	6.10. Building materials, furniture's and chemical	
	products	120
	6.11. Sick Building Syndrome (SBS)	120
	6.12. Indoor air pollution in relation to developing	
	countries	124
	6.13. Exercise questions	135
CH	IAPTER SEVEN: Risk Assessment	136
6	7.1 Learning Objective	136
-	7.2 Introduction to the Chapter	136
	7.3 The health risk assessment and risk	
	management framework	137
	7.4. Epidemiological methods	139
	7.5. Hazard identification in the field	153

7.6. The relationship between dose and health	
outcome	155
7.7. Human exposure assessment	157
7.8. Health risk characterization	171
7.9. Health in environmental impact assessment (EIA)	172
7.10. Exercise question	176
CHAPTER EIGHT: Sampling and Analysis	177
8.1 Learning Objective	177
8.2 Introduction to the Chapter	177
8.3 Ambient Air Quality Standards and Guidelines	178
8.4 Exercise question	184
CHAPTER NINE: Air Pollution Prevention and Control	185
9.1. Learning Objective	185
9.2. Introduction to the Chapter	185
9.3. Control of Ambient Air Pollution	187
9.4. Exercise question	195
REFERENCES	196
APPENDIX	199
Weather- man wind measuring reports system	133
Some questions worth asking about fuel, cooking about fuel, cooking about fuel.	na ana
ventilation	ig and
3 Indoor air eampling procedure	

- 3. Indoor air sampling procedure
- 4. Composition of clean dry Atmospheric air

List of Figures/boxes

Figures

. D	eaths in London Administration country and the	
Ol	uter ring by weeks	53
. R	ange of particles diameters from Airborne Dusts	
ar	nd fumes.	60
. D	eposition of dust particles by size	70
Зох	es	
. Lo	ondon Fog	51
. В	hopal - A case study of an International disaster	89
. м	otor vehicle Air pollution: Health effects and contro	ءُ ا
st	rategies	197
810		
24	oldis • ethio	
	ou. R are are. D	outer ring by weeks Range of particles diameters from Airborne Dusts and fumes. Deposition of dust particles by size London Fog Bhopal – A case study of an International disaster

ABBREVIATIONS

CNS – Central Nerve System

COHb- Carboxihemoglobine.

DALYS – Disability Adjusted Life Years

EPA – Environmental Protection Agency

EPHTI - Ethiopian Public Health Training Initiative

GCMHS – Gondar College of Medical and Health Sciences

IR- Infrared Radiation

LOAEL – Lowest –Observed – Adverse –Effect – Level

M.P.H. – Miles Per Hour

PM – Particulate Matter

TSM – Total Suspended Matter

TSP - Total Suspended Particulates

UOG- University of Gondar

JV- Ultra-Violet rays

VOC- Volatile Organic Compounds

CHAPTER ONE INTRODUCTION

1.1. Learning Objective

After the completion of this chapter, the student will be able to:

- 1. Describe the importance of Air as the basic health requirement of human life
- 2. Define what air pollution means and other related terms
- 3. Enumerate different types of air pollutants
- 4. List physical forms of pollutants

1.2. Introduction to the course

Air is essential for life it self; without it we could survive only a few minutes. It constitutes immediate physical environment of living organisms. It is a mixture of various gases like nitrogen, oxygen and carbon dioxide, and others in traces; along with water vapor perceptible as humidity and suspended solids in particulate form.

how these layers differ and what creates them helps us understand atmospheric function.

TROPOSPHERE

The layer of air immediately adjacent to the earth's surface is called the troposphere. Ranging in depth from about 16 km (10 mile) over the equator to about 8 km over the poles, this zone is where most weather events occur .Due to the force of gravity and the compressibility of gases, the troposphere contains about 80% of the total mass of the atmosphere .Air temperature drops rapidly with increasing altitude in this layer, reaching about -60°C at the top of the troposphere .A sudden reversal of this temperature gradient creates a sharp boundary, the tropopause, that limits mixing between the troposphere and the upper zones.

Other characteristics of troposphere

- All life activities occur in this zone
- Contains water vapor, gases and dust

•

troposphere, the stratosphere has a very similar composition except two important components: water and ozone. The fractional volume of water vapor is about one hundred times lower, and ozone is nearly one thousand times higher than in the troposphere. Ozone is produced by lighting and irradiation of oxygen molecules and would not be present if photosynthetic organisms were not releasing oxygen. Ozone protects life on the earth surface by absorbing most incoming solar ultra violet radiation.

Recently discovered decreases in stratospheric ozone over the Antarctica (and to a lesser extent over the whole planet) are of a serious concern if these trends continue, we would be exposed to increasing amount of dangerous UV rays, resulting in:

- Higher rate of skin cancer
- Problem with eyes (Cataract, conjunctivitis etc.)
- · Genetic mutations
- Crop failures &
- Disruption of important living organisms

Other characteristics of stratosphere

- Contain no water vapor and dust
- Amount of ozone vary depending on location and season of the year. Ozone concentration are lowest above the equator, increasing towards the poles, they also increased markedly between autumn and spring

- Mixing time is lower
- Pollution entering in this region tends to remain long time due to low mixing

MESOSPHERE

Above the stratosphere, the temperature diminishes again creating the mesosphere, or the middle layer. The minimum

The immediate concern of human beings is that the nature of air they breathe for oxygen and respiratory should always be access to human body. The thermal comfort experienced and the smell and hearing sense activated through the medium of air are of other area of health concern.

What is air Pollution?

Air pollution may be defined as any atmospheric condition in which certain substances are present in such concentrations that they can produce undesirable effects on man and his environment. These substances include gases (SOx, NOx, CO, HCs, etc) particulate matter (smoke, dust, fumes, aerosols) radioactive materials and many others. Most of these substances are naturally present in the atmosphere in low (background) concentrations and are usually considered to be harmless. The background concentrations of various components of dry air near sea level and their estimated residence times are given in Annex-1 Thus, a particular substance can be considered as an air pollutant only when its concentration is relatively high compared with the back ground value and causes adverse effects.

Air pollution is a problem of obvious importance in most of the world that affects human, plant and animal health. For example, there is go most serious environmental problems in societies at all level of economic development. Air pollution can also affect the properties of materials (such as rubber), visibility, and the quality of life in general. Industrial development has been associated with emission to air of large quantities of gaseous and particulate emissions from both industrial production and from burning fossil fuels for energy and transportation.

When technology was introduced to control air pollution by reducing emissions of particles, it was found that the gaseous emissions continued and caused problems of their own. Currently efforts to control both particulate and gaseous emissions have been partially successful in much of the developed world, but there is recent evidence that air pollution is a health risk even under these relatively favorable conditions.

In societies that are rapidly developing sufficient resources may not be invested in air pollution control because of other economic and social priorities. The rapid expansion of the industry in these countries has occurred at the same time as increasing traffic from automobiles and trucks, increasing demands for power for the home, and concentration of the population in large urban areas called mega cities. The result has been some of the worst air pollution problem in the world.

In many traditional societies, and societies where crude household energy sources are widely available, air pollution is a serious problem because of inefficient and smoky fuels used to heat buildings and cook. This causes air pollution both out door and indoors. The result can be lung disease, eye problems, and increased risk of cancer.

The quality of air indoors is a problem also in many developed countries because buildings were built to be airtight and energy efficient. Chemicals produced by heating and cooling systems, smoking and evaporation from buildings materials accumulate indoors and create a pollution problem.

In Ethiopia, like many traditional societies, the problem of indoors air pollutions resulted from in efficient and smoky fuels used to heat buildings and cook. In the rural households of Ethiopia, most of the children and women are staying in overcrowded condition of a one roomed /thatched roof /Tukul/ house that exposed them for the indoor air pollution. It is also known that mothers and children are spending more than 75% percent of their day time at home.

Identification of the problems of both at out doors and indoors air pollutions in the societies one has to make interventions to alleviate the health related problems and promote safe ventilation of air in the living and working areas. First, however, some basic science is needed to understand air pollution.

1.3. Historical overview

Human have undoubtedly been coping with a certain amount of polluted air ever since primitive *Homo sapiens* sat crouched by the warmth of a smoky fire in his Paleolithic cave. An inevitable consequence of fuel combustion, air pollution mounted as a source of human discomfort as soon as man begins to live in towns and cities. It has become an extremely serious problem on the world wide basis during the past century for two primarily reasons:

- There has been an enormous increase in world population, particularly in urban areas, and
- The rapid growth of energy intensive industries and rising level of affluence in the developed countries has led to record levels of fossil fuel combustion

Prior to the 20 th Century problems related to air pollution were primarily associated, in public mind at least, with city of London. As early as 18 th Century small amount of coal from Newcastle were being shipped in London for fuel. As the population and the manufacturing enterprises grew, wood supplies diminished and coal burning increased, in spite of the protestation of a long serious of both monarchs and private citizens who objected to the odor of coal smoke. One petitioner to king Charles II in 1661 complained that due to the greed of manufacturers, inhabitants of London were forced to "breath nothing but an impure and thick mist, accompanied by

a fuliginous (sooty) and filthy vapor, which render them

newer pollutants products of the new ubiquitous automobile had assumed worrisome level.

Today foul air has become a problem of global proportions; no longer does one have to travel to London or Pittsburg or Los Angeles to experience the respirat

- transportation-automobiles, industries-refineries, atomic energy plant-nuclear, and community activities-cleaning of streets.
- **1.4.4.** Acute effects: with in twenty four hours of sudden exposure to polluted air illness would occur.
- 1.4.5. Delayed effect: The cause and effect relationship of air pollution and chronic effects on health is in a way difficult to prove due to long time contact and accumulation effect.
- **1.4.6. Aerosols: -** Small solid or liquid particles (fine drops or droplets) that are suspended in air.
- **1.4.7. Dust**: aerosols consist of particles in the solid phase.
- 1.4.8. Smoke: aerosols consist of particles in the solidand sometimes also liquid-phase and the associated gases that result from combustion.
- 1.4.9. Ash: aerosols of the solid phase of smoke, particularly after it settles into a fine dust.
- **1.4.10.Particulates: -** Small particles, that travel in air and settles or lands on something.
- 1.4.11.Fumes: are polydispersed fine aerosols consisting of solid particles that often aggregate together, so that many little particulates may form one big particle.

1.4.12.Inhalable fraction: - Particles less than 100 μm that can be inhaled into the respiratory throat (trachea).

Unit of measurement

Concentrations of air pollutants are commonly expressed as the mass of pollutant per Unit volume of air mixture, as mg/m^3 , $\mu g/m^3$, ng/m^3

Concentration of gaseous pollutants may also be expressed as volume of pollutant per million volumes of the air plus pollutant mixture (ppm) where 1ppm= 0.0001 % by volume. It is sometimes necessary to convert from volumetric units to mass per unit volume and vice versa.

The relation ship between ppm and mg/m³ depends on the gas density, which in turn depends on:

- 3 Temperature
- 3 Pressure
- Molecular weight of the pollutant

The following expression can be uses to convert of between ppm and mg/m³ at any temperature or pressure.

Simply multiply the calculated value $\,$ of $\,mg/m^3$ by 1000 to obtain $\mu g/m^3$

The constant 22.4 is the volume in liter occupied by 1 mole of an ideal gas at standard concentration (0 °c and 1 atm.). One

- 1.6.3 One of the most dangerous modes of transmission of health related problems is, air serves as a vehicle. Therefore poor ventilation of air and overcrowding conditions are creating more favorable situation to the transmission of pollutants.
- 1.6.4 In Ethiopia rural household conditions, where there are more family members, without having enough number of doors and windows and staying at home significant proportion of the day time are highly victims for indoor air pollutions.

1.7. Exercise question

Table 1.1: Exercise on the basic requirements for a healthy environment

Please make a rank according to their degree of importance to health

Using => ++++ Highly important
+++ Moderately important
++ Important
+ Less important

- No important

Parameter	Air	Water	Food	Settlement
Degree of importance				
Degree of accessibility				
Magnitude of health problem				
Risk of pollution at the Global level				
Risk of pollution at the National level				
Manageability level:				
-Globally				
- National				
- Households				
Preventive and control measures:				
- At policy				
- At community				
- At households				
Other parameters that need to be consider				

CHAPTER TWO METEOROLOGY AND AIR POLLUTION

2.1. Learning objective

After the completion of this chapter, the student will be able to:

- Describe the importance of metrology regarding to air pollution
- 2. Identify the importance of environmental and adiabatic laps rate
- 3. State the role of inversion on the concentration of air pollutants
- Analyze plumes behavior in different environmental conditions

2.2. Introduction to the chapter

Meteorology specifies what happen to puff or plume of pollutants from the time it is emitted to the time it is detected at some other location. The motion of the air causes a dilution of air pollutant concentration and we would like to calculate how much dilution occurs as a function of the meteorology or atmospheric condition.

Air pollutants emitted from anthropogenic sources must first be transported and diluted in the atmosphere before these under go various physical and photochemical transformation and ultimately reach their receptors. Otherwise, the pollutant concentrations reach dangerous level near the source of emission. Hence, it is important that we understand the natural processes that are responsible for their dispersion. The degree of stability of the atmosphere in turn depends on the rate of change of ambient temperature with altitude.

Saturated adiabatic lapse rate, (Γ s)

Unlike the dry adiabatic lapse rate, saturated adiabatic lapse rate is not a constant, since the amount of moisture that the air can hold before condensation begins is a function of temperature. A reasonable average value of the moist adiabatic lapse rate in the troposphere is about 6°C/Km.

Example

An air craft flying at an altitude of 9 km draws in fresh air at -40°C for cabin ventilation. If that fresh air is compressed to the pressure at sea level, would the air need to be heated or cooled if it is to be delivered to the cabin at 20°C.

Solution

As the air is compressed, it warms up it is even easier for the air to hold whatever moisture it may have, had .so there is no condensation to worry about and the dry adiabatic lapse rate can be used, At 10°C per km, compression will raise the air temperature by

10x9=90°C making it -40+90°c=50°C

It needs to be the air conditioned

The air in motion is called **wind**, air which is rushing from an area of high pressure towards an area of low pressure. When the weather-man reports the wind to us he uses a measuring system worked out in 1805 by Adoniral Beaufort. For

example, a "moderate breeze" is a wind of 13 to 18 miles an hour (see annex 2).

Obviously air quality at a given site varies tremendously from day to day, even though the emissions remain relatively constant. The determining factors have to do the weather: how strong the winds are, what direction they are blowing, the temperature profile, how much sun light available to power photochemical reactions, and how long it has been since the last strong winds or precipitation were able to clear the air. Air quality is dependent on the dynamics of the atmosphere, the study of which is called *meteorology*

2.3. Temperature lapse rate and stability

The ease with which pollutants can disperse vertically into the atmosphere is largely determined by the rate of change of air temperature with altitude. For some temperature profiles the air is stable, that is, air at a given altitude has physical forces acting on it that make it want to remain at that elevation. Stable air discourages the dispersion and dilution of pollutants. For other temperature profiles, the air is unstable. In this case rapid vertical mixing takes place that encourages pollutant dispersal and increase air quality. Obviously, vertical stability of the atmosphere is an important factor that helps

determine the ability of the atmosphere to dilute emissions; hence, it is crucial to air quality.

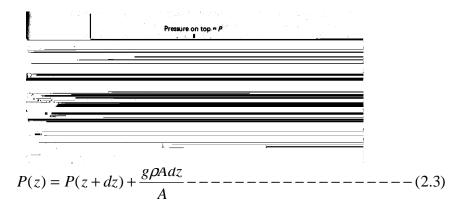
Let us investigate the relationship between atmospheric stability and temperature. It is useful to imagine a "parcel" of air being made up of a number of air molecules with an imaginary boundary around them. If thiscmKcm nr mole

Let us make the quite accurate assumption that as the parcel moves, there is no heat transferred across its boundary, that is, that this process is *adiabatic*

This means that dQ = 0; so we can rearrange (2.1) as

The above equation gives us an indication of how atmospheric temperature would change with air pressure, but what are really interested in is how it changes with altitude .To do that we need to know how pressure and altitude are related.

Consider a static column of air with a cross section A, as shown in figure 2.1 .A horizontal slice of air in that column of thickness dZ and density will have mass AdZ. If the pressure at the top of the slice due to the weight of air above it is P(Z+dZ), then the pressure at the bottom of the slice P(Z) will be P(z+dz) blus the added weight per unit area of the slice it self:



Where: g is the gravitational constant. We can write the incremental pressure dP for incremental change in elevation, dz as $dP = p(z+dz) - p(z) = -g \ dz - \dots (2.4)$

Expressing the rate of change in temperature with altitude as a product, and substituting in (2.2) and (2.3), gives

However, since V is volume per unit mass and $\,$ is mass per unit volume, the product V $\,$ =1 $\,$, and the expression simplifies to

The negative sign indicates that temperature decreases with increasing altitude. Substituting the constant $g = 9.806 \text{m/s}^2$, and the constant -volume specific heat of dry air at room temperature, Cp 1005J/kg. 0C in (2.6) yields



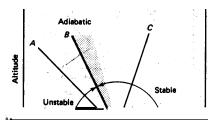
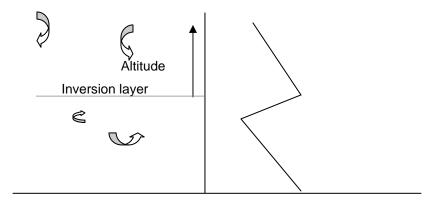


Figure 7.19 Temperature profiles to the left of the adiabatic lapse rate correspond to an unstable atmosphere (line A); profiles to the right are stable (line C). The dry adiabatic lanse rate is:

When the environmental lapse rate (-dT/dz.)Env is greater than the dry adiabatic lapse rate, Γ the atmosphere is said to be super adiabatic. Hence a raising parcel of air, cooling at the adiabatic rate, will be warmer and less dense than the surrounding environment. As a result, it becomes more buoyant and tends to continue it's up ward motion. Since vertical motion is enhanced by buoyancy, such an atmosphere is called unstable. In the unstable atmosphere the air from different altitudes mixes thoroughly. This is very desirable from the point of view of preventing pollution, since the effluents will be rapidly dispersed through out atmosphere.

On the other hand, when the environmental lapse rate is less than the dry adiabatic lapse rate, a rising air parcel becomes cooler and denser than its surroundings and tends to fall back to its original position. Such an atmospheric condition is called stable and the lapse rate is said to be sub adiabatic. Under stable condition their is very little vertical mixing and pollutants

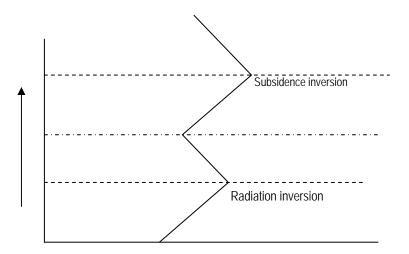


The subsidence is caused by air flowing down to replace air, which has flowed out of the high-pressure region

Radiation Inversion

The surface of the earth cools down at night by radiating energy toward space. On cloudy night, the earth's radiation tends to be absorbed by water vapor, which in turn reradiates some of that energy back to the ground. On the clear night, however, the surface more readily radiate energy to space, and thus ground cooling occurs much more rapidly. As the ground cools, the temperature of the air in contact with the ground also drops. As is often the case on clear winter nights, the temperature of this air just above the ground becomes colder than the air above it, creating an inversion. Radiation inversions begins to form at dusk .As the evening progresses, the inversion extends to a higher and higher elevation, reaching perhaps a few hundred meters before the morning sun warms the ground again, breaking up the inversion.

Radiation inversion occurs close to the ground, mostly during the winter, and last for only



Temperature

The third type of inversion, know as advective inversion is formed when warm air moves over a cold surface or cold air. The inversion can be a ground based in the former case, or elevated in the latter case. An example of an elevated advective inversion occurs when a hill range forces a warm land breeze to follow at high levels and cool sea breathes flows at low level in the opposite direction.

TOPOGRAPHICAL EFFECTS

In large bodies of water the thermal inertia of the water causes a slower temperature change than the near by land. For example, along an ocean coastline and during periods of high solar input, the daytime air temperature over the ocean is lower than over the land. The relative warm air over the land

rises and replaced by cooler ocean air. The system is usually limited to altitudes of several hundred meters, which of course, is where pollutants are emitted. The breeze develops during the day and strongest in mid after noon. At night the opposite may occur, although, usually not with such large velocities. At night the ocean is relatively warm and the breeze is from the cooler land the warmer ocean. The on shore breeze is most likely in the summer months, while the off-shore land breeze more likely occur in winter months.

A second common wind system caused by topographical effect is the mountain - valley wind. In this case the air tends to flow down the valley at night Valleys are cooler at higher elevation and the driving force for the airflow result from the differential cooling. Similarly, cool air drains off the mountain at night and flows in to the valley. During the day light hours an opposite flow may occur as the heated air adjacent to the sun warmed ground begins to rise and flow both up the valley and up the mountain slopes. However, thermal turbulence may mask the daytime up- slope flow so that it is not as strong as the nighttime down - slope flow.

Both the sea breeze and the mountain valley wind are important in meteorology of air pollution. Large power stations are often located on ocean costs or adjacent to large lakes. In this case the stack effluent will tend to drift over the land during the day and may be subjected to fumigation.

2.4. Wind velocity and turbulence

The wind velocity profile is influenced by the surface roughness and time of the day. During the day, solar heating causes thermal turbulence or eddies set up convective currents so that turbulent mixing is increased. This results in a more flat velocity profile in the day than that at night.

The second type of turbulence is the mechanical turbulence, which is produced by shearing stress generated by air movement over the earth's surface. The greater the surface roughness, the greater the turbulence.

The mean wind speed variation with altitude is the planetary boundary layer can be represented by a simple empirical power.

$$\frac{U}{U1} = \frac{Z}{Z1} \alpha - - - - - (2.11)$$

Where: U is the wind at altitude Z

U₁ is the wind speed at altitude Z₁

lpha The exponent varies between 0.14 and 0.5 depending on the roughness of the ground surface as well as on the temperature stability of the atm.

 α = 0.25 for unstable atmosphere

= 0.5 for stable condition

In practice, because of the appreciable change in wind speed with altitude, a wind speed value must be quoted with respect to the elevation at which it is measured. This reference height for surface wind measurement is usually 10 meters

Table 2.1: Wind velocity in different topography

Surface configuration	Stability	α
Smooth open country	Unstable	0.11
	Neutral	0.14
	Moderate stability	0.20
	Large stability	0.33
Flat open country		0.16
Sub-urns		0.28
Urban area		0.40

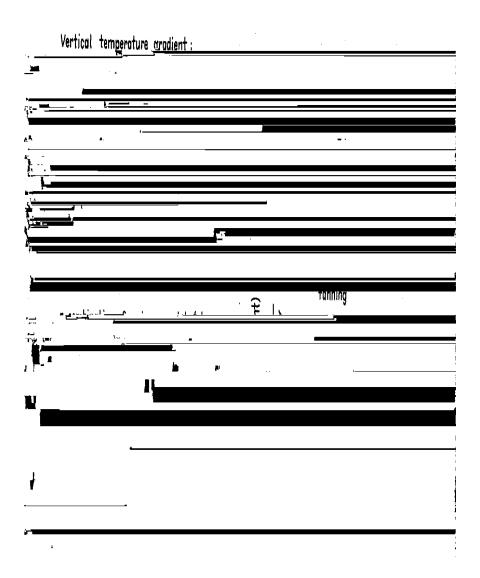
Atmospheric turbulence is characterized by different sizes of eddies. These eddies are primarily responsible for diluting and transporting the pollutants injected in to the atmosphere. If the size of the eddies is larger then the size of the plume or a puff then the plume or the puff will be transported down wind by the eddy with little dilution. Molecular diffusion will ultimately dissipate the plume or the puff. If the eddy is smaller than the plume or the puff, the plume or the puff will be disperse uniformly as the eddy entrains fresh air at its boundary.

2.5. Plume behavior

The behavior of a plume emitted from an elevated source such as a tall stack depends on the degree of instability of the atmosphere and the prevailing wind turbulence.

Classification of plume behavior

 Looping: it occurs under super adiabatic conditions with light to moderate wind speeds on a hot summer after noon when large scale thermal eddies are present. The meteorological condition because the plume does not contribute to ground pollution.



PLUME DISPERSION

Dispersion is the process by which contaminants move through the air and a plume spreads over a large area, thus reducing the concentration of pollutants it contains. The plume

(a) Ground level concentration

In this case Z=0

$$[\rho A](x \ y \ H) \ \frac{Q}{\pi \delta y \delta Z u} \ - \frac{y}{\delta y} \ - \frac{H}{\delta Z}$$

Example 1

A coal burning electric generating plant emits 1.1 kg/ min. of SO_2 from a stack with an effective height of 60m. On a thinly over cast evening with a wind speed of 5 m/ sec. what is the ground level concentration of SO_2 , 500m directly down wind from the stack .

$$\delta y = Ax^{0.903} \qquad \delta z = BX^{P}$$

$$= (0.13) \times 500^{0.90} \qquad = (0.105). (500)^{0.827}$$

$$= 35m \qquad = 18m$$

$$[\rho A](0.5,0,60) = \frac{Q}{\pi \delta y \delta z u^{-}} . \exp \frac{-1}{2} \frac{H}{\delta z}^{2}$$

$$= \frac{18g/\sec}{\pi \times 3.5 \times 18 \times 5} \cdot \exp \frac{-1}{2} \cdot \frac{60}{18}^{2}$$
= 7.4µg

Example 2

A chimney with a design stack height of 250 m s emitting SO2 at a rate of 500g/sec on a sunny day in June with moderate wind speed at a stack altitude, the volumetric flow rate found to be 265m3/sec. , with a wind speed of 6 m/sec: at 10 m level .Estimate the concentration of SO2 down wind for the following situations

(a)
$$(\rho so2) (1000,0,0,250)$$

- (b) $(\rho so2) (1000,50,0,250)$
- (c) $(\rho so2) (1000,50,20,250)$

Solution

On a sunny day in June the incoming solar radiation will be strong. Also, the air will be unstable. A moderate wind speed at the stack altitude will be around 5-7 m/sec. Let us take u = 6m/s. From equation 2.11 the velocity u1 at 10 m level can be obtained:

u1=u
$$(z1/H)^{\alpha}$$
 $\alpha = 0.25$ unstable condition $6(110/250)^{0.25}$ = 2.7 m/sec.

This shows that the surface wind speed is between 2 and 3 m/sec Reference to table 2.1 shows a stability class of A-B we choose B as a conservative answer. The values of can be calculated from the information given in table 2 at a distance of 1000m

$$\delta y = A.x^{0.903}$$
 $\delta z = Bx^{P}$
= 0.295(1000) $^{0.903}$ = 0.119(1000) $^{0.986}$
= 151m = 108m

(a)
$$[\rho so2](1000,0,0,250) = \frac{500x10^6}{\pi(151)(108)6} \exp \frac{-1}{2} \frac{250}{108}^2$$

=112µg/m³

(b)
$$[\rho so_2]($$
) $\frac{Q}{\pi \delta y \delta z u}$ $-\frac{y}{\delta y}$ $-\frac{H}{\delta z}$

Plume rise

Estimation of plume rise

1. Buoyant plumes

In the case of buoyant plumes, the influence of buoyancy is much greater than the influence of vertical momentum. Such plumes are usually obtained when the release temperatures are more than 50 c greater than ambient atmospheric temperatures.

Holland's equation

$$\Delta H = \frac{Vs.Ds}{U^{-}} 1.5 + 2.68x10^{-3} pa.\frac{Ts - Ta}{TS}.Ds - - - - - (2.18)$$

Where: Vs = stack gas exit velocity, m/s

Pa = atmospheric pressure, mb

Ts = stack gas temperature, k

Ta =ambient air temperature

U - =wind speed, m/sec.

Ds = Diameter of stack out let, m

2. Plume rise under stable and calm conditions

When there is little or no wind, the bending of the plume is negligible small and it rises to some height where the buoyancy force is completely dissipated. The recommended equation for such a situation is

$$\Delta H = 5F^{1/4}$$
. S $^{-3/8}$ ----- (2.19)

$$F = gvs \frac{Ds}{2}^{2} \cdot \frac{Ts - Ta}{Ts}, \frac{m^{4}}{s^{2}} - - - -(2.20)$$

CHAPTER THREE SOURCES, TYPES OF AIR POLLUTANTS AND THEIR EFFECTS

Respiratory symptoms are the most common adverse health effects from air pollution of all types. Table 1.1 presents a summary of major health effects thought to be caused by community air pollution. Respiratory effects of air pollution, particularly complicating chronic bronchitis, may place an additional strain on the heart as well.

3.3. Common condition to which air pollution exposure may contribute

Air pollution is associated with increased risk of death from heart disease and lung disease, even at levels below those known to be acutely toxic to the heart. Mucosal irritation in the form of acute or chronic bronchitis, nasal tickle, or conjunctivitis is characteristic of high levels of air pollution, although individuals vary considerably in their susceptibility to such effects.

The eye irritation is particularly severe, in the setting of high levels of particulates (which need to be in the respirable range described and may be quite large soot particles) or of high concentrations of photochemical oxidants and especially aldehydes.

There is little evidence to suggest that community air pollution is a significant cause of cancer except in unusual and extreme cases. However, emissions from particular sources may be cancer-causing. Examples of cancer associated with

community air pollution may include point-source emissions from some smelters with poor controls that release arsenic, which can cause lung cancer. Smoke from cigarettes is generally much more highly carcinogenic than air pollution could be.

Central nervous system effects, and possibly learning disabilities in children, may result from accumulated body burdens of lead, where air pollution contributes a large fraction of exposure because of lead additives in gasoline.

Table 3.1: Examples of Common Conditions to Which Air Pollution Exposure May Contribute

Disease or	How air pollution	
condition	may affect it	Associated factors

These health effects are better characterized for populations than for individual patients. Establishing a relationship between the symptoms of a particular patient and exposure to air pollution is more difficult than interpreting the likely health effects on an entire community.

It is important to understand that these pollutants are seasonal in their pattern. Both ozone and sulfates, together with ultra fine particulates, tend to occur together during the summer months in most developed areas. Ozone, oxides of nitrogen, aldehydes, and carbon monoxide tend to occur together in association with traffic, especially in sunny regions.

Some pollutants, such as radon, are only hazards indoors or in a confined area. Others are present both indoors and outdoors, with varying relative concentrations.

3.4. Types of pollutants

3.4.1 CONVENTIONAL

Sulfur Dioxide

Sulfur dioxide was a serious problem in air pollution in the earliest days of industrialization. It has been the major problem in reducing or acidifying air pollution during the period of rapid economic growth in many countries. It was one

of the major components of the so-called London Fogs, which had serious direct health effects as illustrated in Box 5.1.

In 1953, Amdur et al. studied the effects of sulfur dioxide on humans and found that, at least in acute exposures, concentrations of up to 8 ppm caused respiratory changes that were dose dependent. (This is one of the first studies to use physiological measurements as an indication of the effects of air pollution.) Later studies revealed that the main effect of sulfur dioxide is broncho constriction (closing of the airways causing increased resistance to breathing) which is dose dependent, rapid, and tended to peak at 10 minutes (Folinsbee, 1992). Persons with asthma are particularly susceptible and in fact asthmatics suffer more from the effects of sulfur dioxide than does the general public. Persons with asthma who exercise will typically experience symptoms at 0.5 ppm, depending on the individual.

Sulfate, the sulfur-containing ion present in water, remains a major constituent of air pollution capable of forming acid. Sulfate itself appears to be capable of triggering broncho constriction in persons with airways reactivity and it is a major constituent of ultrafine particulates. There are other acid ingredients in air pollution, such as nitric acid, but less is know about them. These acids, though, cause a phenomenon known as acid rain, with their emission into the air by industry and motor vehicles.

Because of their small size and tendency to ride along on particulates, acid aerosols such as sulfur dioxide, sulfates and nitrogen dioxide tend to deposit deeply in the distal lung and airspace. They appear to provoke airways responses in an additive or synergistic manner with ozone. They have also been implicated in causing mortality in association with ultra fine particulates.

SO₂ and sulfates are the principal chemical species that cause acid precipitation. They may be transported long distances in the atmosphere away from their source and result in acidification of water and soils.

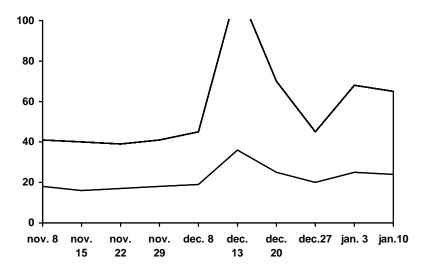
BOX 5.1: London Fog

On December 5, 1952, a phenomenon known as a temperature inversion occurred in the atmosphere, in London, England. This resulted in a dense fog forming in the center of the city of London. (During a temperature inversion very little air movement occurs, and air, including the particle matter and other pollutants it contains, gets trapped in a given location. Suspended matter in the air can provide nuclei on which particles of moisture and other pollutants, such as acids, are deposited.)

During this time, the temperature hovered around 0 degrees Celsius. The burning of fossil fuels (coal) in open earth fires in

Figure 1: Deaths in London Administration County and the Outer Ring by Weeks.

November 1952 - 10 June 1953



Based on the epidemiological data collected during the London smog episodes, it was felt at the time that the increased number of deaths in London during the fog was more closely related to the particulate matter in the air, rather than the SO₂. A reanalysis later, though, suggested that the acid aerosols (e.g. sulfur dioxide) was the major factor in causing the increased mortality.

Adapted by A. Morham; from Kjellstrom and Hicks, 1991

Nitrogen Dioxide

Nitric oxide (NO) is produced by combustion. Nitrogen dioxide (NO₂), which has greater health effects, is a **secondary pollutant** created by the oxidation of NO under conditions of sunlight, or may be formed directly by higher temperature combustion in power plants or indoors from gas stoves. Levels of exposure to nitrogen dioxide that should not be exceeded (WHO guideline levels) are respectively 400 μ g/m³ (0.21 parts per million (ppm) for one hour and 150 μ g/m³ (0.08 ppm) for 24 hours (WHO, 1987a).

The direct effects of nitrogen oxide include increased infectious lower respiratory disease in children (including long-term exposure as in houses with gas stoves) and increased asthmatic problems. Extensive

in Table 2.3. Other effects are known but difficult to evaluate. For example, NO has a major effect on blood distribution in the lungs. In animals, it has been shown that exposure to NO_2 makes metastases to the lung from cancer elsewhere in the body much more likely, although NO_2 does not itself cause cancer. These unusual effects are difficult to interpret and understand.

NO₂ is also a significant contributor to acid precipitation.

Table :- 3.2. Potential Human Effects of Nitrogen Dioxide

Health Effect	Mechanism
Increased incidence of respiratory infections	Reduced efficacy of lung defenses
Increased severity of respiratory infections	Reduced efficacy of lung defenses
Respiratory symptoms	Airways injury
Reduced lung function	Airways and possibly alveolar injury
Worsening of the clinical status of persons	
with asthma, Chronic obstructive pulmonary	
diseases or other chronic Respiratory condition	ns Airways injury

Source: Samet and Utell, 1990

Particulates matter

Particle matter in the air (aerosols) is associated with an elevated risk of mortality and morbidity (including cough and bronchitis), especially among populations such as asthmatics and the elderly. As indicated, they are released from fireplaces, wood and coal stoves, tobacco smoke, diesel and automotive exhaust, and other sources of combustion. The US Environmental protection Agency (EPA) sets a standard of 265 μ g/m³ in ambient air, but does not have a standard for indoor air levels. Usual concentrations range from 500 μ g/m³ in bars and waiting rooms to about 50 μ g/m³ in homes (Brooks et al., 1995). In developed countries, tobacco smoke is the primary contributor to respirable particles indoors.

Particulate matter (PM 10)

Larger particulates, which are included in PM_{10} (particulates 10 μm and smaller) consist mostly of carbon-containing material and are produced from combustion; some fraction of these are produced by wind blowing soil into the air. These larger particulates do not seem to have as much effect on human health as the smaller particulates.

Particulate matter (PM 2.5)

In recent years we have learned a great deal about the health effects of particles. As noted above, particulates in urban air pollution that are extremely small, below $2.5~\mu m$ in diameter,

are different in their chemical composition than larger particles. Particulates in the fraction $PM_{2.5}$ (2.5 μ m and below) contain a proportionately larger amount of water and acid-forming chemicals such as sulfate and nitrate, as well as trace metals. These smaller particulates penetrate easily and completely into buildings and are relatively evenly dispersed

Although the effect of air pollution is clearly present in the statistics, air pollution at levels common in developed countries is probably much less of a factor in deaths and hospital admissions than the weather, cigarette smoking, allergies, and viral infections. However, the populations exposed to air pollution are very large, and even if only 5% of all excess deaths during a one-week period are related to air pollution in a major city, a reasonable estimate, this means that thousands of deaths

northern Chinese cities, for example, has been attributed to air pollution and this is likely to be true, however, cigarette smoking, indoor air pollution from coal-fired stoves, crowded conditions and the risk of viral infections may also be important factors.

There remains much more work to do to understand this problem, but the essential message seems clear: at any level, particulate air pollution and possibly ozone are associated with deaths, and both are clearly associated with hospital admissions and health risks.

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Hydrocarbons

Most hydrocarbons such as aliphatic and salicylic hydrocarbons are generally biochemical inert at ambient

3.4.2 NON-CONVENTIONAL

Asbestos

Asbestos is a mineral fiber that has been used as insulation and as fire retardant in buildings. Many asbestos products have been banned, and its use is now limited. But in older buildings asbestos is still found in pipe and furnace insulation, asbestos shingles, floor tiles, textured paints, and other construction materials. If these materials are disturbed cutting, sanding or other activities, excessive air borne asbestos levels can occur. Improper attempts to remove these materials can also release asbestos fibers in to the indoor air. As a guide line, average asbestos levels should not exceed 0.1 fibers/ML for fibers longer than 5µm.

Health effects

- Asbestosis(lung scaring)
- Mesothelioma (cancer of the lung and the abdominal lining)
- Lung cancer

Mercury

It is present in gaseous form in the atm. because of its relatively high vapor pressure. The gaseous mercury is washed from the air by rain a portion of it enters the aquatic system and the remaining is bound to the soil over the land. In

both cases the inorganic mercury is generally concurred in to its methyl or diethyl cpds by the action of bacteria.

Beryllium

Most beryllium emissions are in the form of metallic powder of beryllium oxide particulate. A chronic condition brown as berylliosis is thought to be caused by beryllium concentration as low as 0.01 to $0.1 \mu g/m^3$. It is systematic poisoning which starts with progressive;

- Shortness of breaths
- Weight loss
- Cough
- Cardiac failure

Fluorides

Vegetation damage attributed to atmospheric fluoride has been accused from:

- Copper smelters
- Super phosphate
- · Glass and enamel factories
- Aluminum plants
- Hydrogen (fluoride manufactory plant

Animal may develop fluorites (accumulation in bone) could results in

- Lameness
- · Loss of weight
- Dental flour sis

Ozone

Ozone is a highly reactive compound that irritates airways in the lungs and interferes with host defense mechanisms in the body. It also has an unusual effect on breathing patterns as the result of changes in the reflex breathing mechanism.

In the lower atmosphere, oxygen, with light from the sun as a source of energy, reacts with nitrogen compounds and volatile hydrocarbons to create ozone. This occurs especially in stagnant weather conditions and inversions under conditions of sunshine, where there is ample time for the photochemical reactions to take place. Ozone is chemically unstable, and will react with a variety of substances.

The way in which ozone affects humans appears to be complicated, and dependent on activity level and pollutant concentration, among other factors. Ozone appears to attack the epithelial cells in the bronchial tree, which in turn may cause airway inflammation and hyper responsiveness in the first place, although this has been hard to prove.

The WHO guidelines are 150–200 $\mu g/m^3$ (0.076–0.1 ppm) for one hour exposure and 100–200 $\mu g/m^3$ (0.05-0.06 ppm) for 8 hour exposures (WHO, 1987a).

Physical Forms of Pollutants

The constituents of air pollution may exist in any of the three phases of matter; they may be solid, liquid or gas. Often all three are present at once, especially in very small particulates.

Aerosols

Small solid or liquid particles (fine drops or droplets) that are suspended in air are called aerosols. Aerosols in air pollution are complex systems. They often consist of a mixture of solid-phase particles, combined solid- and liquid-phase particles, and sometimes liquid droplets. Even aerosols that are predominantly solid may contain absorbed water.

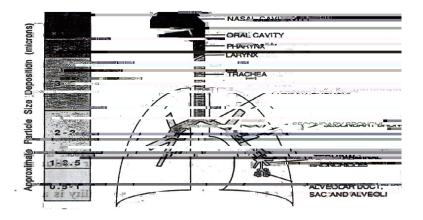
The most important characteristic that predicts the behavior of aerosols are size and composition. Size predicts how the particle will travel in air and composition determines what will happen when it settles or lands on something. Small particles are called **particulates**.

The individual particles in aerosols may be relatively uniform in size (monodispersed) or highly variable in size (**polydispersed**). Aerosols in air pollution are all polydispersed. **Fumes** are polydispersed fine aerosols consisting of solid particles that often aggregate together, so that many little particulates may form one big particle.

The effects that will be seen from a particular aerosol depend on how many of the particles there are of a particular size. Size is also related to mass; the smaller the particle, the less mass. In all polydispersed aeros combustion. These small particles generally consist of a matrix of carbonaceous compound, some water, and dissolved or absorbed or solid-phase sulfate, nitrate, and trace metals. They may form from nitrates and sulfates in the air coming together in a solid form. They have different effects on the body than larger particles and are considered more toxic. The composition of an aerosol also determines the chemical reactivity of its individual particles and their density.

The effect of particulates on the body reflects the efficiency with which they penetrate all the way to and within the lung and their chemical reactivity and toxicity once they arrive. Larger particles carry much more substance but are much less likely to cause an effect on the body because they do not penetrate into the lower respiratory tract (below the first division of the windpipe, or trachea). The largest particles visible to the naked eye as specks of dust, are mostly filtered out in the nose. Particles above 100 µm may be sources of irritation to the mucous membranes of the eyes, nose, and throat but they do not get much further. Those particles below this cut-off are called the inhalable fraction because they can be inhaled into the respiratory throat (trachea). Those particles below 20 µm generally do not enter the lower respiratory tract, below the throat (trachea). Those particles below 20 µm are called the thoracic fraction because they can penetrate into the lungs. Particles below 10 µm enter the airways with greatest efficiency and may be deposited in the alveoli, or air spaces, that are the deepest structures of the lungs. Notwithstanding the efficiency of penetration, particles smaller than about 0.1 µm tend to remain suspended in air and to be breathed out again. Thus, as a practical matter the greatest penetration and retention of particles is in the range 10.0 to 0.1 µm, which is called the respirable range. These patterns of deposition are shown graphically in Figure 2.

Once in the lung, particles may have different effects



Reprinted from Newman, 1992

Figure 2: Deposition of Dust particles by size

Although it is disregarded for purposes of measuring the size of the particle, shape is important in determining the effects of a particle. The human body handles longer and thinner particles, which are called **fibers**, differently from particles that are more rounded in shape. Fibers are more difficult to remove from the lungs by natural protective mechanisms. There is also good evidence that the very long and thin shape of fibers of asbestos plays an important role in the damage it can cause in the lung.

Liquid phase

Liquid constituents of air pollution exist as aerosols, either as liquid-phase particles, which are **droplets**, or in association

with solid-phase particles. Liquids that are constituents of air pollution are always aqueous, or water-based, because droplets of more volatile organic compounds evaporate to the gaseous phase very quickly. A cloud or dense collection of droplets is called a **mist.**

Small solid-phase particles also contain a small amount of absorbed water. Both liquid and gas-phase constituents of air pollution often are attracted to and ride on the surface of solid particles; this is called **adsorption** (not to be confused with absorption, in which the liquid or gas is actually taken into the particle).

The humidity in the atmosphere is an important determinant of the water content of particles; the lower the humidity, the faster the water dries out and the particle is reduced to a solid phase. Dry particles may take on water when they are released into a humid atmosphere. Small particles typically absorb large amounts of water if it is available in the atmosphere; they are said to be **hygroscopic**.

compound in the gas phase is called a **vapor** and behaves like a gas in air pollution. Droplets may also form from condensation of vapor in a saturated atmosphere. Fog is a familiar example of an aerosol of liquid water droplets that forms from condensation in an atmosphere saturated with liquid around a small solid particle. In coastal areas, the droplets of seawater may evaporate to form solid-phase particulates that contain salt.

Precipitation, in the form of rain and snow, reduced air

and sulfur dioxide. They may also coalesce to form ultra fine particles. (In addition, there are a number of gases more common as occupational exposures that are water-soluble, including hydrochloric acid vapor, and ammonia). Relatively insoluble constituents include the oxides of nitrogen and ozone. (Likewise, relatively insoluble occupational exposures include these and also phosgene, chlorine, and nitrogen dioxide.)

Solubility for gases is much like size for particles; it is a characteristic that determines the efficiency with which they penetrate deeply into the respiratory tract. A gas that is soluble in water will be dissolved in the water coating the mucous membrane of the lungs and upper respiratory tract and will be removed from air passing more deeply. A gas that

compounds. The degree to which they enter the blood and are circulated and are then delivered to the body's tissues depends on the concentration inhaled, duration of exposure, solubility in blood and tissue, reactivity of the compound and the respiratory rate. (The respiratory rate determines how much air is breathed in and therefore the total amount taken into the body.) To understand the health problems associated with airborne contaminants it is essential to have at least a basic understanding of the structure and function of the respiratory tract.

Anything that decreases the partial pressure of oxygen in the alveoli reduces the oxygen available for exchange and, therefore, has an asphyxiating effect. At high altitude, the partial pressure of oxygen in alveoli air decreases, reducing the saturation of blood with oxygen. Substances that dilute or displace the oxygen in air without any other effect are simple asphyxiants. Examples include carbon dioxide, nitrous oxide, nitrogen or hydrocarbons such as natural gas. Compounds that block the transfer of oxygen to the tissues or the utilization of oxygen once it reaches the tissues are called chemical ae

common place as a product of incomplete combustion of fuels (such as in automobile exhaust or open-flame heaters) and is especially dangerous because of its lack of an odor to give warning of exposure.

Chemical agents that irritate the lung may also impair oxygen uptake by different means. Irritants may inflame the respiratory tract, causing bronchitis or provoking an asthmatic attack, or causing the lungs to be filled with fluid (pulmonary edema), a process much like drowning. Usually the more highly water soluble the compounds, the higher in the respiratory tract they exert their effect.

Unlike many toxic substances that are ingested, inhaled compounds are not significantly metabolized prior to

compounds, they cause indirect effects (such as helping to create ozone) as well as having direct human physiological effects. They may originate from household products such as painting supplies, dry cleaning establishments, refineries, gasoline stations and many other sources. They can cause irritation to the respiratory tract (from increased rhinitis, or runny nose, to asthma) as well as headaches and other non-specific complaints. At high concentrations, they have markedly toxic effects, some of which vary by compound, but

3.5. Magnitude and Sources of Ambient Air Pollution

Exposure to air pollution is part of urban living throughout the world. Over the past 20 years there has been a shift in the type of air pollution affecting developed countries, as the traditional pollutants from stationary sources (such as SO₂ and suspended particulate matter [SPM]) have been effectively controlled by the implementation and enforcement of legislation in many developed countries. Also, a change from domestic coal burning to electricity and natural gas for heating and cooking purposes has lead to a lower level of emissions of SO₂ and SPM with a concomitant improvement in air quality. However, further economic development (and increasing personal wealth) has resulted in increase in industrial emissions, and especially in motor vehicle traffic. This in turn, has led to increases in pollutants associated with motor vehicle transport; most notably NOx, carbon monoxide and hydrocarbons, as well as ozone and other photochemical oxidants and lead in many jurisdictions (see Box 3. for more on motor vehicle air pollution). Attempts to control emissions, primarily through the introduction of catalytic converters and more fuel efficient engines, have largely been outstripped by growth in motor vehicle traffic (see Mage and Zali, 1992). Meanwhile, in many developing countries, rapid urbanization has resulted in a duplication of many of the problems faced by developed countries, remain high. In addition, rapid economic development has meant emissions from industry and motorized vehicles are increasingly causing air quality problems.

Urban environments generate their own microclimates (especially mega cities), which cause special problems. Air pollution trapped in urban areas by stagnant air, especially in a valley, may accumulate and may undergo chemical reactions that change its character. Some of the most severe situations of air pollution are in these world megacdities, such as Mexico City and Sao Paulo (Brazil), and in cities in the developing world, such as shenyang (China). Also, many heated buildings can create a difference in ambient air temperature between urban and rural environments. This in turn can contribute to temperature inversions (a phenomenon with multiple causal factors which prevents warm air from rising. This leads to a concentration of air pollution, as noted earlier). People examining, and attempting to control urbanization must take these difficulties into consideration. For the United States in 1989, approximate percentages of sources for some of the pollutants are indicated in Table 8 and for Sao Paulo in Table 9. It can be seen that in both situations, transportation and industry are the major sources of pollutants.

Table 3.3: Sources of Pollutant Emissions, United States, 1989

	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Volatile Organic
Transportation	25%	4%	66%	40%	35%
•	22%	80%	13%	56%	5%
Fuel consumption					
Industrial	39%	16%	8%	3%	44%
Solid wastes	3%	0%	3%	1%	3%
Miscellaneous	12%	0%	11%	1%	14%

Source: Statistics Canada, 1994

Table 3.4: Major types of occupational pulmonary disease

Pathophysiolog	Occupational	Clinical history	Physical	Chest x-ray	Pulmonary	_		
process	disease		examination		function			
	example				pattern			
Fibrosis	Silicosis	Dyspnea on exertion, shortness of	Clubbing, cyanosis	Nodules				
	Asbestosis	breath		Linear				
			Clubbing,	densities,				
Reversible airway	Byssinosis,	Dyspnea on	cyanosis,	pleural				
obstruction	isocyanate	exertion,	rales	plawues,				
(asthma)	asthma	shortness of		calcifications				
		breath	Respiratory					
Emphysema			rate↑, wheeze	Usually				
	Cadmium	Cough, wheeze,		normal				
	poisoning	chest tightness,	Respiratory					
Granulomas	(chronic)	shortness of	rate ↑	Hyperaeration				
		breath, asthma	↑ expiratory	bullae				
Pulmonary	Beryllium disease	attacks	phase					
edema		Cough, sputum,	Respiratory					
	Smoke inhalation	dyspnea	rate 1					
		Cough, weight	Coarse,		С	-	3	
		loss, shortness of	bubble rales	low DLCO Usually	y			
		breath		decr042sd Tj0 -1. Chypoxemia a	3759 TD.0026 Tc	.uDLCO,		
		Frothy, bloody		3 1	802 TD .0020	Tc0038 Tv	w [(rDLf T7(COf T8(=)ffus
		sputum production		(,,,, =			[(= = (= = (,

Table 3.5: Common air pollutants, their sources and pathological effects on man

Ser. No.	Pollutants	Where they come from	Pathological effect on man
1	Aldehydes	Thermal decomposition of fats,	Irritant nasal and respirator tract
		oil or glycerol	
2	Ammonia	Chemical processes dye-	

3.6. Exercise question

Study Exercise

- Š Consider the implications of particulates and gaseous constituents of: 1) wood smoke, 2) cigarette smoke, 3) automobile exhaust, 4) emissions from a coal-fired power plant.
- š Which has the most pollutants of air pollution matter? Which is predominantly gas? Which is most complicated chemically? Which is likely to be most dangerous?
- š Explain the effects of SO₂ on man?
- Š Describe the harmful effects of NO₂ on living things and the environment?
- š Define Aerosol, dust and smoke?
- š Describe the toxicological effects of CO in blood?

4.3. Types of Industrial Air Pollutants

There are three general types of industrial air pollution as defined by their different chemical characteristics, distribution, and sources (outlined in Table 6). **Reducing** air pollution is caused by the emission of sulfur dioxide (SO_2) and particulates, substances that are chemical reducing agents in the atmosphere. This is by far the oldest type of air pollution. Emissions of SO_2 are caused by burning fossil fuels mining coal containing some sulfur, emissions of particulates occur most heavily when combustion is inefficient. Reducing air pollution is produced primarily by stationary combustion sources, such as fossil fueled power plants, industrial furnaces and steel mills. This type of air pollution has predominated in older basic industry.

Table 4.1: Types of Air Pollution by Chemical Characteristics and Source

Туре	Composition	Source		
Reducing	Sulfur dioxide, particulates.	Stationary combustion		
		sources, Such as fossil fuel		
		power plants, industrial		
		furnaces, home heating		
		units.		
Photochemical	Hydrocarbons and nitric	Mobileemissions		
	oxide emitted by sources such as			
	internal combustion engine undergo)		
	automobiles, fossil fuel power Complex			
	photochemical reactions in the plants			
	and oil refineries. Presence of sunlight,			
	resulting in an atmosphere with significant			
	concentrations of ozone, nitrogen dioxide,			
	aldehydes, and organic nitrates.			
Point Source	Specific to source of emission, e.g. lead			
	Specific industries; near a smelter.	Industrial or		
		transportation		
		accidents.		

Photochemical air pollution, much newer in human history, results from complicated chemical reactions in the atmosphere that are driven by the energy in sunlight. In photochemical smog, emissions rich in oxides of nitrogen and hydrocarbons undergo reactions to produce ozone, specific

compounds of nitrogen and aldehydes -all of which are highly reactive and chemically oxidizing. This type of smog is caused primarily by automobile traffic, to which are added emissions from mobile sources, such as hydrocarbons from gasoline and dry cleaning solvents and oxides of nitrogen from power plants. Many cities have been able to bring reducing air pollution under control. However, as automotive traffic has increased worldwide, photochemical smog has emerged as a problem.

A third type of industrial air pollution is **point-source emissions.** This type affects the immediate vicinity of the plant, but does not usually involve atmospheric reactions to any great extent. Examples include lead in the vicinity of a smelter, hydrogen sulfide from a sewer gas well, pesticides from agricultural application, and concentrated fumes from a

one in the US in 1948 (Donora, Pennsylvania), one in Mexico in 1950 (Poza Rica), two in England in 1952 and 1962 (both in London – see Box 1.), and one in India in 1984 (Bhopal). The Bhopal incident is presented in Box 2.

BOX 2.

Bhopal - A Case Study of an International Disaster

Argualbly, the world's worst industrial cataclysm occurred on 2 December 1984 at the Union Carbide Plant in Bhopal, India, where a release of a gas cloud of methylisocyanate killed over 3800 people.

With respect to the historical facts leading up to the disaster, it is noteworthy that the post-World War II era witnessed a dramatic world-wide increase in the production of organic chemicals. The application of pesticides in particular was encouraged and became widely prevalent. Although the impacts on occupational and environmental health were beginning to be realized, the necessity for greater food production despite inadequate safety testing lead to the continued use of these chemicals in everyday life. Early in the 1970s governments of many developed countries recognized the need to adopt a proactive role for government intervention and regulation in this area. This, combined with the fact that markets in developed countries approached saturation, lead to the multinational corporations turning their attention to the developing world, where public health concerns for occupational and environmental health were low. These conditions lead to an increase in the international mobility of hazardous products, industry, and wastes to these lucrative markets of cheap labour, with only its costs and relative indifference to occupational and environmental health standards.

What was described in one report as a "normal accident" was apparently initiated by the introduction of water into the MIC storage tank, resulting in an uncontrollable reaction, with liberation of heat and escape of MIC and other decomposition products in the form of a gas. Safety systems were either not functioning or were inadequate to deal with large volumes of the escaping toxic chemicals.

Among the more than 200,000 persons exposed to the gas, the initial death toll within a week following the accident was over 25,000 by 1990, the Directorate of Claims in Bhopal had prepared medical folders for 361 966 of the exposed persons. Of these, 173382 had temporary injuries and 18922 had permanent injuries, with the recorded deaths totaling 3828.

One of the most important lessons of the Bhopal tragedy is how important it is to prevent these incidents by taking action in advance. Environmental legislation, preventive maintenance strategies,

worker-training programmes, environmental education programmes, research on intermediate products, development of systematic hazard-evaluation models, emergency planning, and disaster preparedness are all examples of such ac

4.5 Air Pollution in the Workplace

Airborne hazards are common problems in occupational health. Several diseases are known to be caused by inhalation of substances found in particular occupations. For each category of disease noted in Section 5.2, there are long

lists of workplaces where such diseases have been documented to be excessive due to inadequate air quality controls. The incidence and prevalence of these conditions have changed over time. For example, the fibrotic lung diseases (those that cause scarring of the lungs) used to be quite prevalent, and still are in developing countries where exposure controls are inadequate. This category of diseases includes silicosis, asbestosis, coal miners' pneumoconiosis, and others. Occupational lung cancer, chronic obstructive lung diseases and chronic bronchitis are well documented as occurring in association with workplace exposures. Occupational asthma is now increasingly common, with the list of substances known to be capable of causing asthma growing rapidly.

Suffice it to note that there are by far more cases of disease caused by air pollution inside a workplace than by exposures to the general community outside. Also, for many people, the distinction between the work environment, the home, and the general environment is an artificial distinction. Exposure control in the community should always be linked to exposure control inside the plant, and the fact that exposures are usually much higher inside the plant should always be taken into account in prioritizing prevention activities.

CHAPTER FIVE GLOBAL ENVIRONMENTAL PROBLEMS DUE TO AIR POLLUTION

5.1. Learning Objective

After the completion of this chapter, the student will be able to:

- 1. Describe the factors that contribute for global warming
- 2. Identify the different green house gases.
- Enumerate the potential adverse health effects of global warming.
- List different international responses to ozone depletion.

5.2. Introduction to the chapter

The CO₂ concentration in the atmosphere is 25% higher than what it was at the beginning of the century. Large scale deforestation, burning of chemical and fossil fuel have created this increase. Climatologists believe that even a small increase atmospheric CO₂ can have major effects on climate. CO₂ is transparent to incoming visible sun energy, but like glass, it absorbs infrared heat reradiated from the earths surface. This is called green house effect. The earth planet has already been warmed by 0.8 to 2.5°C and is going to get

hotter by 3 to 5°C within the next country It is feared that even a slight increase in temperature would cause the polar ice caps to melt and rise the sea level, submerging a number of major cities of the world, because many are along the seacoast.

5.3. Global warming

What is global warming?

- The fate of solar energy when reached the earth
- Absorption by earth and natural green house gases (CO₂, CH₄, water vapor); Infrared radiation reflection by earth's crust;
- Infrared radiation absorption by the green house gases;
- ³ Infrared radiation retention by green house gases;
- Resulting in an acceptable level of temperature at the earth at 15°C
- Could have been 19⁰C less if the reflected heat from the earth escaped to the space.
- IR absorption by green house gases as a function of concentration of these gases.

Anthropogenic (man made) "green house gases" and their sources:

- 1. CO₂: fossil and bio-mass fuel burning, forest fire, etc.
- 2. N₂O: N₂

- 3. CH₄: animal dung decomposition, waste landfills, wet lands, etc
- 4. CFCs: factories.
- 5. CO₂ and CFCs are main contributors to IR absorption:
- 1980 UNEP IR absorption contribution: 55%, 24%, 15%
 6% by CO₂, CFCs, CH₄, Nitrous oxide, respectively

Potential health effects due to global warming

General points:

- Average earth's temperature variation:
- 0.6°C/past 100 years; forecasted: 1-3.5° C/next 100 years
- (an increase of 1°C/700 yrs versus today 1°C/35 yrs).
- An increase of 2^oC would result events not seen before
 125 000 years ago. Variations in climatically factors:
 wind velocity, rainfall, etc.
- Variations in the ability to respond to the effects: economics and susceptibility.

Effects: Direct and Indirect:

A/ Direct effects:

 Thermal extreme effect: (heat waves) the skin, CNS and Circulatory system the most affected: thermoregulation disturbance; heat stroke and exhaustion, decreased male fertility, cerebro-vascular stroke, etc.

- 2. <u>Effect on the respiratory organs:</u> persons with chronic diseases like asthma, bronchitis, cardiovascular are the most affected.
- 3. <u>Weather instability and natural calamities:</u> cyclones, land slides, draught, flooding, etc.

B/ Indirect effects:

 Vector borne diseases: mosquitoes (malaria, yellow fever, rift valley fever); Tsetse fly (African sleeping

5.4. OZONE DEPLETION

Identity: found in stratosphere in nature as O₃; its detection in troposphere (ground level) is an indicator of pollution.

Its role:

- Ø Solar radiation: 55% IR; 40% visible light; 5% UV.
- Ø Acts as a UV protective blanket (layer).
- UV radiation includes three bands: UVA (400-320nm);UVB (320-280nm); UVC (280-200nm), far UV (< 50nm).
- Ø It blocks nearly all UVC, half UVB, and small part UVC.

Mechanism for UV blocking:

- \emptyset Equilibrium in nature between destruction and production of O_3 .
- Ø O₂ O+O (energized by UVC)
- Ø $10+O_2$ $O_3 + IR$ (production of Ozone)
- \emptyset O₃ + UV O₂+O: (destruction of Ozone as energized by UVB)

What causes Ozone depletion?

- Human activity: release of halogenated hydrocarbons:
 CFCs; CCI₄;
- Are used as refrigerants, propellants, solvents, foam production, etc.
- Are stable under normal conditions in the troposphere.

 These volatile chemicals become active with the presence of UV to react with O₃;

The reaction:

- 1. $CCI_2F_2 + UV \quad CCIF_2 + CI^2$
- 2. $Cl^{-} + O_3$ $ClO + O_2$
- 3. CIO +O $CI^{-} + O_2$
- 4. Net: O₃+O 2O₂ (Chlorine atom acts as a catalyst).

Potential adverse effects:

- UVC is absorbed by O₃, (does not reach the earth);
- UVB and UVA reach the earth.

A/ Direct effect:

1. Skin damage and cancer:

- Acute exposure: thermal extremes due to UV: sun burn; skin lesions;
- Cumulative (chronic) exposure: skin cancer in fair skinned humans;
- UNEP estimates: 5% skin cancer increase during 2070's (extra 100 cases of skin cancer per million population per year) in Europeans living at around latitude 45 degrees N)

2. Effects on eye:

3. Effects on immune system

Skin sensitivity; animal tests; possible effects.

B/ Indirect effects:

- Effects on plants: impairs photosynthesis & UVB; farm productivity declining
- Effects on aquatic system: Phytoplankton & UVB; aquatic farm productivity declining. CO₂ take up will be diminished.

INTERNATIONAL RESPONSE TO OZONE DEPLETION:

 The <u>Montreal Protocol</u> on substances that deplete the ozone layer in 1987, and its amendments in London (1990) and Copenhagen (1992);

Issues in the protocol:

- · Ozone depletion is actually observed;
- Few products were involved in the depletion:
 CFCs, methyl chloroform, methyl bromide.
- Few producers were involved.
- A climate Convention signed in RIO De-Janioro in June 1992; (Agenda 21).
- 3. The Kyoto (Japan) protocol signed in March 1998;
- 4. A legal binding ratification by protocol signatories is underway

Perspectives of operating in harmony with climate and weather

- Biometeorology and bioclimatology: for climate changes study and assessment;
- · Early warning systems;
- · Building designs and Urban planning;
- Disaster mitigation planning;
- Environment and sustainable development.

5.5 Acid rain

ACID DEPOSITION

Rain fall by nature is slightly acidic due to the tendency to each chemically with atmospheric CO2. Forming a weak solution of carbonic acid with PH 5.6, by definition any ppt measuring less than 5.6 on the pH scale is considered acid rain.

$$CO_2+H_2O====H_2CO_3====H+HCO_3$$
 PH=log 10[1/H $^+$]

Carbonic acid created by CO2 in air

- Volcanic emission
- Biological decomposition
- Chlorine & sulfates from ocean spray can drop the pH of ppt below 5.6 while, alkaline dust can raise the pH above 7

Acid rain is only one form in which acid deposition occurs. Fog, snow, mist, and dew also trap and deposit atmospheric contaminants. Furthermore, fall out of dry sulfate, nitrate, and chloride particles can account for as much as half of the acidic deposition in some areas.

Extent of the problem

A factor that complicates the acid rain problem and makes finding a solution difficult is its regional and continental scale. Most oxides of sulfur and nitrogen are emitted from tall stacks at power plants in order to increase the dispersion and dilution of the stack gases. This may protect near by communities from the immediate effect of air pollution, discharge from tall chimneys allows the pollutants to be carried for long distance in the atmosphere. The pollution in its effect is" air mailed" to other regions and even to other continents. It is estimated that 50% of the acid rain in eastern Canada comes from the USA, and about 25 % of the acid rain in the New England originates from Canadian sources. In addition, acid rain in Norway is believed to come mostly from industrial areas in Great Britain and continental Europe.

Formation of acid rain

SO_2 H_2SO_4	62 %
NO ₂ HNO ₃	32%
CIHCI	6%

In urban areas, where transportation is the major sources of pollution, nitric acid is equal to or slightly greater than sulfuric acid in the air.

Environmental effect of Acid Rain

1. Damage to aquatic life

Reproduction is the most sensitive stage in the life cycle

Eggs and fry of many fish species are killed at pH 5.0

Disrupt the food chain by killing:

Plants

Aquatic Insects

Invertebrate on which fish dependent on food

At pH level less than 5

- Adult fish die
- Trout, salmon
- Game fish

Acidity

- Alters body chemistry
- Destroy gills prevent oxygen up take
- Causes bone decalcification
- Disrupt muscle contraction

Phytoplankton population are reduced, and many common water, dowelling invertebrates such as may flies and stone flies can not survive when the Ph falls below 5.5

Acid dead lakes have pH below about 3.5

2. Deterioration of buildings and monuments

Most glorious buildings and works of art are being destroyed by air pollution:

- Smoke and soot coat buildings
- Paintings
- Textiles
- Lime stone and marble are destroyed by atmospheric acid at an alarming rate

Air pollution also damages

- Ordinary buildings
- Corroding steel
- Weakens buildings, roads, bridges
- Rubber deterioration

3. Mobilization of toxic metal

Acid rain can cause lightly bound toxic metals such as aluminum which can kill fish by damaging their gills and causing asphyxiation.

It also cause leaching of heavy metals: Hg, Cd in to drinking water and results in Bio accumulation

4. Damage to forest productivity

In 1983 in Germany some 34 % of the forest was affected and in 1985n, more than 4 billion hectares (50%) were reported to be in the state of decline Show evidence of:

- Root necrosis
- Lack of seeding growth
- Premature tree death
- Growth reduction
- Defoliation

High altitude forests are subjected to especially intense doses of these acids because clouds saturated with pollutants tend to hang on , mountain tops, bathing forests in a toxic soap for days even weeks at a time

5. visibility reduction

Particulates in the atmosphere reduce the visibility due to scattering and absorption of light. The dust particles of 2000/Cm3 can obscure a mountain at 75 km; while a concentration of NO₂ of 20 ppm would probably reduce the visibility to 1 km. NO₂ causes the sky to appear brownish in color in addition to reducing visibility.

A relationship between the concentration of the particulate in the atmosphere, and the visibility can be developed as follows

$$Lv = 5.2 \rho r/kc$$

Where: Lv Visibility

K scattering area ratio

C particulate concentration

ρ Particle density

r particle radius

5.6. Exercise question

EXERCISE QUESTIONS

- 1. What is global warming?
- 2. What is acid rain and its effect?
- 3. Describe the direct and indirect health effects of global warming?
- 4. List the cause of ozone depletion? And its potential health effects?

CHAPTER SIX INDOOR AIR POLLUTION

6.1. Learning Objective

After the completion of this chapter, the student will be able to:

- 1. Differentiate indoor and outdoor air pollution.
- 2. Identify the source type and effect of indoor air pollution.
- 3. List different control measures of indoor air pollution.

6.2. Introduction to the chapter

Inefficient combustion and smoky fuels burned for cooking and heating are a troubling source of serious air pollution in many traditional and developing societies. The use of such fuels causes air pollution problems both indoors and outdoors.

The quality of air indoors is a problem in many buildings in developed countries because they were built to be airtight and energy efficient. Chemicals from burning fuels, smoking and other sources in the building accumulate and create a pollution problem. Indoor air pollution is also a serious problem in many developing societies. In homes where open fires burn, especially when the climate is cold, the pollution

from the fires accumulates and exposes the inhabitants, especially women, to the risks associated with smoke inhalation. The result can be serious lung disease and an increased risk of cancer, as occurs in some parts of China among women who tend fires in homes heated with coal.

Indoor air pollution has been identified as one of the foremost global environmental problems (World Bandk, 1993). An SPM level of 50-100 µg/m³ may cause health effects (WHO, 1987a). Rural people in developing countries may receive as much as two thirds of the global exposure to particulates. Women and young children suffer the greatest exposure.

Indoor air pollution contributes to acute respiratory infections in young children, exacerbation of asthma, chronic lung disease and cancer in adults, and adverse pregnancy outcomes for women exposed during pregnancy. Acute respiratory infections, principally pneumonia, are the chief killers of young children, causing a loss of 119 million disability adjusted life years (DALYS) per year or 105 of the total burden of disease in developing countries (World Bank, 1993). Data from the Gambia, Nepal, South Africa, the United States, and Zimbabwe suggest that reducing indoor air pollution from very high to low levels could potentially halve

The most important indoor air contaminants in developed countries are tobacco smoke, radon decay products, formaldehyde, asbestos fibers, combustion products (such as NO_x, SO_x, CO, carbon dioxide and polycyclic aromatic hydrocarbons), and other chemicals used in the household. Several microbiological air contaminants are also of importance including moulds and fungi, viruses, bacteria, algae, pollen, spores and their derivatives. In airtight buildings especially (e.g. buildings which are energy efficient, but with poor ventilation), indoor air pollutants can accumulate, causing tight building syndrome.

6.3. Environmental tobacco smoke

It is a self evident air pollutant from combustion that many people produce knowingly in the home, despite the warnings of adverse health effect. ETS is a mixture of more than 4000 compounds, at least 40 of which are carcinogenic and many of which are strong irritants. Indoors tobacco smoke can harm occupants as well as the smoker; ETS is also refereed to as second hand or side stream smoke, and exposure to it is often called passive smoking.

The EPA of USA in 1992 concluded that exposure to ETS is responsible for about 3000 lung cancer deaths each year in non smoking adults.

In addition to second hand smoke, other sources of in door combustion products include

- stoves
- space heaters
- fire places
- chimneys

Pollutants from these sources include, CO, NO₂. and particulate.

Kerosene space heaters may also emit SO₂ and acid aerosols.

Short term health effects of exposure to ETS:

- irritation of the eye, nose and throat
- · aggravate asthma

6.4. Radon gas

Radon is colorless, odorless, radioactive gas that is the part of a natural decay process beginning with uranium and ending with lead.

Radon gas seeps in to homes from the soil, brick concrete and stone. It is believed to be produced from radio active by product of stone and soil under the house. The level and effect of radon accumulation is very high in unventilated buildings. It is estimated in USA 10% of lung cancer deaths may be attributed to radon gas exposure. Therefore radon is believed to be a carcinogen.

A simplified description of the sequence, along with half-lives, alpha, gamma, and beta radiation emitted. It is found in varying concentrations in soils and rocks that make up the earth's crust. Because it is the gas, radon flows easily through the porous soil and fissures in rock. When it reaches to the ground surface, the gas dispersed and diluted to very low concentrations in the out door environment.

Radon itself is inert, but it's short lived decay products (Radon progeny): polonium, lead and Bismuth, are chemically active and easily become attached to inhaled particles that can lodged in the lungs. In fact, it is the alpha emitting polonium, formed as radon decays, that causes the greatest lung damage.

Radon captured in the ground water, to be released when that water is aerated, such as during showers (the radon risk in water is from inhalation of the released gas, not from drinking the water itself). A level of 10000 Pci/l of radon in water will produce about 1 pci/l of radon in indoor air.

Radon gas and its radioactive daughters are known carcinogens and may be the second leading cause of lung cancer after smoking. The EPA estimates that between 5000 and 20000 lung cancer deaths per year in the USA can attributed to household radon exposure

The degree of risk depends on:

- total exposure time
- average radon concentration in the home

Formaldehyde is a colorless, pungent-smelling gas that cause eye and throat irritation, nausea, and respiratory distress in some people exposed to high concentrations. It has also been shown to cause cancer in animals and may cause cancer in humans, Average concentration in older homes (envisions generally decrease over time) are generally below 0.1 mg lm³, in homes with significant amounts of now pressed wood products, levels can exiled 0.3 mg /m³ A suggested guideline is for elves not exceed 0.12 mg/ m³.

Formaldehyde emissions increase with to and humidity thus, the use of dehumidifiers and air conditioning can help reduce indoor concentrations. Increased ventilation rates also reduce formaldehyde resins rather than UF resins.

6.6. Asbestos

Asbestos used to be common building material formed in structural fire proofing, heating systems installation, floor and ceiling tiles and roofing felts and shingles. It has been also used in fires place, gloves, ironing board covers and certain hair driers.

6.7. Lead

Lead is a harmful environmental pollutant. People can be exposed to lead in drinking water and food, as well to lead dust in the air. The most significant sources of lead dust old

binding at neighboring sites. The carbon monoxide molecule's bond to hemoglobin is 200-300 times stronger than is the hemoglobin- oxygen bond, so carbon monoxide is not cleared easily from the circulatory system. Exposure to short periods of high concentration of carbon monoxide is just as bad as long periods of low concentrations. Normal amounts of carbon monoxide in the blood are in the range of 1%. Smokers can have higher concentrations, and if one were to exercise at rush hour in heavy traffic (at 10-15 ppm), levels of 3-4% could be expected.

Table 6.2: Predicated Carboxyhaemoglobin Levels for Subjects Engaged in Different Types of Work

Carbon	monoxide tration	Exposure Time Predicated COHb Level for those engaged in			
ppm	mg/m³		sedentary work	light work	heavy work
100	115	15 minutes	1.2	2.0	2.8
50	57	30 minutes	1.1	1.9	2.6
25	29	1 hour	1.1	1.7	2.2
10	11.5	8 hours	1.5	1.7	1.7

Source: WHO, 1987a

Different predicated **carboxyhaemoglobin** levels for subjects engaged in different types of work are shown in Table 5.4 Different LOAELs (lowest-observed-adverse-effect-level) are shown in Table 2.7 Exercise tolerance does not seem to be decreased until after a level of about 5% is reached in healthy

subjects. People at increased risk include those with heart and lung problems. It h9k(/hide)5.4E fond lun

Table 6.3: Human Health Effects Associated with Low-Level Carbon Monoxide Exposure: Lowest-Observed-Adverse-Effect Levels Carboxyhaemoglobin effects Concentration (%)

2.3 – 4.3	statistically significant decrease (3-7%) in the relation between work time and exhaustion in exercising young healthy men
2.9 – 4.5	statistically significant decrease in exercise capacity (i.e. shortened duration of exercise before onset of pain) in patients with angina and increase in duration of angina attacks
5 – 5.5	statistically significant decrease in maximal oxygen consumptions and exercise time in young healthy men during strenuous exercise
< 5	No statistically significant vigilance decrements after exposure to carbon monoxide
5 – 7.6	statistically significant impairment of vigilance tasks in healthy experimental subjects
5 – 17	Statistically significant diminution of visual perception, manual dexterity, ability to learn, or performance in complex sensorimotor tasks (e.g. driving)
7 – 20	Statistically significant decrease in maximal oxygen consumption during strenuous exercise in young healthy men

Source: WHO, 1987a

6.9. Biological Contaminants

Airborne contaminants of a biological nature include bacteria fungi viruses' animal dander, dust mites, pollen, and other tiny forms or products of life. There are many sources of these biological pollutants contaminated central heating or cooling systems can become breeding grounds and the distribute these contaminants throughout the home standing water - water damaged materials or wet surfaces can also serve as

house mites, animal dander, pollen and other allergic causing agents.

6.10. Building materials, furniture's and Chemical products

A wide Varity of household products contain formaldehyde and other hydrocarbons. These include foam insulation floor covering (caplet) and textile products, furniture polish disinfections etc.

6.11. Sick Building Syndrome (SBS)

Indoor air pollution is not limited to individual homes many multistory commercial and office buildings have significant air quality problems A number of well identified illnesses (for example Legionnaire's disease) have been directly traced to specific building problems. Three are called building related illnesses.

When the occupants of building have symptoms that do not fir the pattern of any particular illness and are difficult to trace to a specific source, the phenomenon is referred to as trace to specific source, the phenomenon is referred to as sick building syndrome. This term is applied to building when more than 20 percent of its occupants complain of health problems for 2 weeks or more and the symptoms are relieved when the

Sick building syndrome usually can not be effectively remedied with out a comprehensive air quality survey and investigation these investigations may begin with questionnaires and telephone interviews to assess the nature and extent of occupant symptoms. the ventilation system is often the most important factor to investigate; inadequate ventilation accounts for about half of sick building syndrome cases>Air quality testing may help to identify contaminants, but air sampling and analysis are not always effective in solving the problem due to the very low levels of pollutants.

Table 6.4: Sources and exposure guidelines of indoor air contaminants

Pollutant and indoor sources	Guidelines, average concentrations	
Asbestos and other fibrous	0.2 fibers/ml for fibers longer than 5	
aerosols	μm	
Friable asbestos; fireproofing,		
thermal and acoustic insulation,		
decoration, Hard asbestos: vinyl		
floor and cement products.		
Carbon monoxide	10 mg/m³ for 8 hr, 40 mg/m³ for 1	
Kerosene and gas space heaters,	hr	
gas stoves, wood stoves, fireplaces,		
smoking.		
Formaldehyde	120 μg/ m³	
Particleboard, paneling, playwood,		

carpets, ceiling tile, ureaformaldehyde foam insulation, other construction materials.

6.12. Indoor air pollution in relation to developing countries

Indoor-air pollution in the context of developing countries

About **3.5 billion people** in less developed countries, still rely on biofuels (wood, dung and crop residues) for domestic energy [WRI 98]. Fuels are typically in open fires or simple stoves, often indoors, and rarely with adequate ventilation or chimneys. This situation leads to some of the highest ever recorded levels of air pollution, to which young children and women in particular are exposed for many hours each day [Smith 87, Smith 93].

Although smoke from biofuels contains thousands of substances, many of which may be harmful to health, it is particulates that are thought to best describe the health-damaging potential of this pollution. Particles are defined by their diameter, expressed in microns. Smaller particles of less than 10 microns (PM₁₀) are thought most harmful due to their ability to penetrate into the lungs. Concentrations are expressed as the weight of PM₁₀ (μ g/m³) of air sampled. Current US EPA recommendations are that average 24 hour PM₁₀ levels should exceed 150 μ g/m³ only once in 100 occasions (99th percentile level), and that the annual average should not exceed 50 μ g/m³. The revised World Health

Organization air quality guidelines for Europe, reflecting the growing evidence that there appears to be no safe lower limit for particulate exposure, has not recommended 'levels' of PM_{10} . Instead, exposure-response data for mortality, respiratory symptoms, and service use are presented. Given this ever more cautious attitude towards particulate air pollution in the developed world, it is striking that typical 24 hour average PM_{10} concentrations in developing country

Threat to children's health

Dependence on polluting solid fuels to meet basic energy

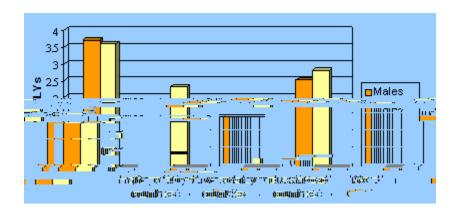
ALRI have now been published. The studies reporting positive results indicate an increase in risk of ALRI for exposed children of between 2 and 5 times. Although this suggests that reducing IAP exposure could be a powerful preventive intervention for ALRI [Kirkwood 95], there remain important gaps in our knowledge:

- The size of any effect on ALRI incidence is uncertain, which in turn means there is uncertainty about the potential that reduced IAP exposure has for prevention of ALRI.
- The exposure-response relationship has not been quantified, with the result that it is not known by how much exposure needs to be reduced in order to achieve useful health gain. This has important implications for implementation because there are currently substantial technical and economic barriers to achieving large reductions in exposure among many poor communities for whom pollution is worst.

Disease burden by level of development

The importance of indoor air pollution as a public health threat varies drastically according to the level of development: in high-mortality developing countries, indoor air pollution is responsible for up to 3.7% of the burden of disease, while the

same risk factor no longer features among the top 10 risk factors in industrialized countries.



Disease burden (DALYs) due to indoor air pollution by level of development - 2002

WHY DOES THE BURDEN PERSIST?

There are a number of reasons why the burden on child health associated with IAP persists, and these can be broadly summarized as follows:

- The limitations of the scientific evidence on causation.
- There are technical and economic barriers to achieving substantial exposure reductions, especially in poor s' n.36ing10.02 probl(sub)emd ducD 002.440

technical, community and policy options, and collaboration between organizations and agencies responsible for **health**, **energy**, **housing** and **development**.

Interventions

The following interventions may be used alone or in combinations to reduce exposure to IAP

Technical interventions

Infant protection - Keeping children away from smoke exposure.

- Ø The linkages between fuel, food, water, women=s time and women=s health warrant further exploration.
- Ø Dung-work illustrates the linkage between women=s work and their status.
- Where biomass fuels are commonly used, similar rates in women and men are now being found for diseases such as chronic bronchitis and *cor pulmonale*; age of onset of *cor pulmonale* in women is early.
- Ø Women's respiratory disorders in India are linked to domestic exposure to cooking smoke; however, respiratory disease in women often goes untreated.
- Ø Undetected pneumoconiosis in rural women may be caused by a combination of dust from maize grinding and smoke from biomass fuel.
- Ø High lung cancer rates in Chinese women can be attributed to the combined effects of passive smoking and the domestic use of poor quality coal.

DEVELOPMENT REPORT - WHO/Air Pollution

The United Nations World Health Organization says millions of people die earlier than they should because of indoor air pollution. It says most victims live in developing countries. Dietrich Schwela is a pollution scientist for the W-H-O. Mr. Schwela says people need to be informed about the dangers of indoor air pollution. He says many people do not know that

the air found in buildings can injure and sometimes kill. The WHO scientist says indoor air pollution is common in developing countries because people there use open stoves. They cook food on the stoves. And, the devices produce heat for their homes.

Mr. Schwela says that many houses in developing countries do not use chimneys. Chimneys are tall, narrow structures with an opening at the top. They usually are made of building materials or metal. The opening of the chimney should rise through the top of the building. A fire can be built at the bottom of the chimney. Chimneys permit smoke to travel up and out of the house. They protect people in the house from breathing in much of the smoke. Mr. Schwela says chimneys in developing countries often are not built correctly. He says this is especially true in African nations. The W-H-O scientist

children in India die each year from indoor air pollution. In Africa, about that many children die from the problem.

Mr. Schwela advises people not to use open stoves. He says they also should not use wood and some other natural fuels inside buildings. Mr. Schwela says natural gas and kerosene are much better fuels for cooking and heating. And, he says people should have working a chimney that sucks smoke out of the house.

HEALTH EFFECTS OF WOOD SMOKE

In developing countries, woodsmoke has had a serious effect on human health as some wood stoves emit smoke to indoor air.

In Sydney, studies by the NSW EPA found that most of the particulate pollution in winter came from 13% of households using wood heaters. Studies also showed that death rates are generally higher in winter on days of high pollution, or days following high particle pollution.

Wood smoke is estimated to be 12 times more carcinogenic than an equal concentration of cigarette smoke'.

In a laboratory study, mice were subjected to either wood smoke; oil furnace fumes or clean air for 6 hours. They were then challenged with a streptococcus bacterium and within two weeks, 21% of the mice exposed to wood smoke were dead compared with 5% of the mice exposed to the oil furnace fumes or clean air.

Autopsies have shown that particles less than 2.5 microns in diameter (PM2.5)are retained in human lungs. Larger

6.13. Exercise questions

- 1. What is the difference between indoor and outdoor air pollution?
- 2. What are the common types indoor air pollutants in your community?
- 3. Do you think that indoor air pollution as a significant health problem than outdoor air pollution in Ethiopia? If so, how?
- 4. List some of the general measures of controlling indoor air pollution.

CHAPTER 7 RISK ASSESSMENT

7.1. Learning Objective

After the completion of this chapter, the student will be able to:

- 1. Define the elements of risk assessment;
- 2. Understand the types of information needed for each element of risk assessment;
- 3. Describe how hazards can be identified in the field;
- 4. Describe the types of extrapolation required for the assessment of dose-response;
- 5. Explain the difference between threshold and non-threshold effects;
- 6. Provide several examples of useful markers ofeC305sreeshold effects;

Table7.1. Several of the Many Sources of Uncertainty in a Risk Assessment

- Š Use of an experimental study involving an inappropriate route of exposure;
- Š Differences in biokinetics and/or mechanism of toxicity between species;
- Š Poor specification of exposure in experimental study i.e. concentration, duration, route, chemical species;
- š Extrapolation high dose to low-dose situations;
- Š Difference in age at first exposure or life-style factors between an experimental group and a risk group;
- š Exposure to multiple hazards in epidemiology studies;
- š Potential confounding factors;
- š Misclassification of the health outcome of concern.

Adapted from Hallenbeck, 1993

When the health risk of a specific environmental hazard or situation has been characterized, decisions must be made regarding which of the various control actions should be taken. Regulatory agencies may develop regulatory options,

A number of different types of epidemiological studies may be used for formal testing of hypotheses. These are discussed below.

7.4.2. Study Methods

Epidemiological study types differ considerably in their strengths and weaknesses. Table 7.2 summarizes the main features of the major traditional types of epidemiological studies.

There are only so many ways to study the association between a cause and a disease, injury or other health condition. One may see what the situation is at the time of the study. One may start with the cause and see what happensal

Table 7.2. Study Designs in Environmental Epidemiology That Use the Individual as the Unit of Analysis

Study	Population	Exposure	Health effect	Confounders	Problems	Advantages
design						
Descriptive study	Community or various sub-populations	Records of past measurement s	Mortality and morbidity statistics; case registries; case registries; other reports	Difficult to sort out	Hard to establish exposure-effect relationships	Cheap, useful to formulate hypotheses
Cross- sectional study	Communities or special groups; exposed vs. non-exposed	Current	Current	Usually	Current	Can be done quickly; can use large populations; can estimate prevalence
Prospective cohort study	Community or special groups; exposed vs. non- exposed	Defined at outset of study (can change during study)	To be determined during study	Usually easy to measure	Expensive, tie consuming exposure categories can change; high dropout rate possible	Can estimate incidence and relative risk; can study many diseases in one study; can describe associations that suggest cause-effect relationships

Historical	Special groups	Records of past	Records of	Often difficult	Need to rely on	Less expensive and
cohort study	e.g. workers,	measurement	past or	because of	records that may not	quicker than
	patients,		current	retrospective nature;	be accurate	prospective study; can
	insured		diagnosis	depends on disability		be used to study
	persons			of previously		exposures that no
				obtained data		longer exist
Case-control	Diseased	Records or	Known at	Possible to eliminate	Difficult to	Relatively cheap and
study	(cases)vs. non-	interview	start of	by matching	generalize; may	quick; particularly
	diseased		study		incorporate biases;	useful for studying
	(control)				cannot derive rates	rare diseases
Experimental	Community or	Controlled	To be	Can be controlled by	Expensive; ethical	Well accepted results;
(intervention	special groups	/known already	measured	randomization of	consideration; study	strong evidence for
s study)			during	subjects	subjects' compliance	causality or efficacy or
			study		required	intervention

Source: WHO, 1991a

An Approach to classification of studies designs

Table 7.3 provides a framework for analyzing both historical and prospective cohorts' studies according to four sets of criteria. These criteria address defining the study cohort, quantifying exposure, ascertaining mortality, and analyzing results. The definition of a study cohort is in turn evaluated according to the method of cohort selection, criteria for inclusion or exclusion of cohort members, the extent to which the subjects selected for study included all eligible workers, and the adequacy of the size of the cohort. Similarly, quantifying exposure will take into account the amount of detail contained in work history files, the extent of industrial hygiene data, the quality of industrial data, and whether there is a likely impact of any confounding factors. With respect to ascertaining mortality, it is necessary to consider the quality of the follow-up (i.e. the method employed to determine whether subjects are alive or dead at the end of a study), the completeness of the follow-up procedure, the availability of death certificates or other records that list causes of death, and the length of the follow-up period. Finally, analysis of results depends on the appropriateness of the external control group employed in the study, the availability of an internal control group, whether the study takes into account the delay, or latency periods associated with disease development, the use of appropriate statistics, demonstration of an exposure gradient, and a discussion of possible sources of bias. These

factors are discussed at length in various epidemiological publications.

Table 7.3. Assessing the Quality of Historical Cohort Studies

- 1. Definition of the Study Cohort
 - (a) Method of selection
 - (b) Criteria for inclusion or exclusion
 - (c) Extent to which all cohort members were considered
 - (d) Size of the cohort
- 2. Quantification of Exposure
 - (a) Detail in work history files
 - (b) Extent of industrial hygiene data
 - (c) Quality of industrial hygiene data
 - (d) Consideration of confounding factors
- 3. Ascertainment of Mortality
 - (a) Quality of follow-up technique
 - (b) Completeness of follow-up
 - (c) Availability of death certificates or other records to determine the cause of death
 - (d) Length of follow-up

4. Analysis of Results

- (a) Suitability of the external control group
- (b) Availability of an internal control group
- (c) Allowance for latency effects
- (d) Use of appropriate statistics
- (e) Demonstration of an exposure gradient
- (f) Discussion of possible biases

Figure 7.1: Definition and Calculation of Rates of Disease and Risk Ratios

RATE OF DISEASE: Number of cases of disease in population at risk

Number of persons in population at risk

EXPRESSED AS: Number of cases

100 or 1000, etc. persons at risk

EXAMPLE: 50 cases 1000

2500 persons at risk

RISK RATIO: Rate of disease in population with the risk factor

Rate of disease in population without the risk factor

the populations with the risk factor (e.g. those who are exposed to asbestos) are five times more likely to have or get the disease (e.g. lung cancer) than the population without the risk factor (e.g. those who were not exposed to asbestos).

A **risk ratio** is the most widely used from of risk measure. It is defined as "the ratio of the risk of disease or death among the exposed to the risk among the unexposed". Other measures

BOX 7.1

Common Measures of Risk Derivable from Epidemiological Studies

Risk Difference =
$$E - U$$

Risk Ratio =
$$\frac{E}{U}$$

Attributable Fraction (Exposed) = $\underbrace{\text{(E-U)}}_{E}$ =(through mathematics) $\underbrace{\text{(RR-1)}}_{RR}$

Attributable Fraction (Population) = $\frac{I-U}{I}$ = $\frac{[p(RR-1)]}{[p(RR-1)+1]}$

Where U = incidence (or mortality) in the unexposed group;

E = incidence (or mortality) in the exposed group;

P = prevalence in the total population;

The most frequently employed method of evaluating mortality in an occupational epidemiological study is to calculate the **standardized mortality ratio (SMR)** for the group. The SMR is the ratio of the observed deaths in a group divided by the number of deaths that would normally be expected in a group with a similar age distribution.

SMR = Observed number of deaths (or events) in the study populationx100%

Expected number of deaths (or events) if the study population had the same age and gender composition as the comparison (e.g. national) population

The denominator of the SMR (e.g. the expected number of deaths) is computed as follows:

- A calculation is made of the person-years at risk in the cohort (the number of individuals in the cohort multiplied by the number of years that each individual has been followed).
- The figure obtained is multiplied by the expected mortality rate for the disease(s) being considered. The expected mortality rates can be obtained from national population statistics.

An SMR of 130 for a particular cause of death indicates that there was a 30% greater mortality of that disease found than was actually expected.

Since these measurements of risk are statistical, we can not be sure that the observations in a study did not occur by chance. The statistical significance of these measures are usually expressed in a **confidence interval**. For example, if a number falls within a 95% *confidence interval*, one can be 95% sure that the ratio is correct. That also means that there is a 5% chance that the study's results occurred by chance. The width of the confidence interval depends on the number of cases observed, the size of the population in the study, and the variability of the comparison or expected rates. These issues are discussed at greater length in *Basic Epidemiology*, *Environmental Epidemiology*, and other WHO publications.

7.4.4. Study Difficulties and the Determinants of Causation

Some form of analytical epidemiological study is usually necessary to establish the cause of a disease, although descriptive studies can give a strong indication of causation at times. The choice of study depends on the particular situation. It will vary according to the nature of the disease in question, its frequency in the population, the frequency of postulated risk factors, the availability of resources, the experience and preference of the environmental health professionals available, among other things. (See publications such as *Environmental Epidemiology*, WHO, for more details.)

In determining the degree of weight that should be placed on the evidence obtained from an epidemiological study, it is necessary to distinguish between the concepts of **association** and **causation**. A causal relationship implies that the disease has been shown to be actually induced by the environmental agent. There are numerous reports in scientific literature alleging links between environmental agents and disease outcome. Therefore, guidelines are needed to asses the likelihood that the association is a cause-and-effect relationship. The most widely accepted were originally conceived by British statistician Sir Austin Bradford Hill, and are shown in Table 7.4. These guidelines are not absolute, but are useful in achieving consensus about whether a known risk factor is likely a true cause of the disease in question.

Table 7.4: Tests of Causation

- Š Temporal relation: Does the cause precede the effect? (essential)
- Š Plausibility: Is the association consistent with other knowledge?
- š Mechanism of action: Is there evidence from experimental animals?
- š Consistency: Have similar results been shown in other studies?
- Strength: what is the strength of the association between the cause and the effect? (relative risk)
- Š Dose-response relationship: Is increased exposure to the possible cause associated with increased effect?
- š Reversibility: Does the removal of a possible cause lead to reduction of disease risk?
- Š Study design: Is the evidence based on a strong study design?
- Š Judging the evidence: How many lines of evidence lead to the conclusion?

Source: Beagle Hole et al., 1993

The main weakness of epidemiological studies about environmental pollutants is that they are relatively inefficient in proving that exposure to a particular substance is associated with the health effects observed. A major limitation of most studies is the statistical possibility that a real association with be detectable in the study. For example, in order to detect a two-fold increase in major congenital malformations (with 95% certainty that an increase found was not a chance finding, i.e. =.05; =0.20), more than 300 live births would have to be studied, as shown in table e.5.

7.5. Hazard identification in the field

Based on toxicological and epidemiological data, potential health effects of hazardous substances can be indicated. These research methods applied to identify environmental hazards have been introduced. However, recognizing hazards in a specific situation requires a different approach. More often, it is done by monitoring purchases of toxic substances and by conducting health hazard evaluations and hazard audits, both of which involve walking through the plant (or community facility) and investigating all operations. The difference between the two is that in a health hazard evaluation the walk-through is intended to identify the cause of a particular problem but in a hazard audit all potential hazards are systematically examined.

7.5.1. Occupational Environment

In the workplace it can be relatively easy to make an inventory of all potential hazards. This is made easier by an accurate registration or tracking system of all chemicals that are frequently used or stored, which unfortunately is not always the case. In order to make an inventory of chemical hazards, product identity is, of course, crucial. From knowledge of which product is used one may then learn what is in it and what constituents are hazardous. Identifying the chemicals in a product may be difficult if the manufacturer is not required by law to list ingredients, or if the material is not labeled properly, or if the composition of the product is protected as a trade secret.

7.5.2. General Environment

In contrast to the occupational environment, the identity of chemical hazards is usually difficult in uncontrolled environments, such as illegal dumping sites or abandoned industrial locations. For example, the chemical hazards at a suspected soil contamination may be almost anything. One way is to check whether there is information within the community regarding former industrial or other activities at the suspected location. Based on the results of such an inquiry further research can be streamlined in a specific direction. However, if no records exist or no industrial activities can be

described by former workers, the situation becomes far more difficult. In such a situation, chemical analysis of samples will have to be conducted to determine the nature of the contamination. Since it is too costly to screen for all possible contaminants, chemical analysis has to be concentrated on specific *marker* components.

7.6. The relationship between dose and health Outcome

7.6.1. Dose-Effect and Dose-Response Relationships

The terms 'dose-response' and 'dose-effect' are often used as being the same in meaning. Strictly speaking, however, dose-response relationship describes the relationship between the proportion of individuals in an exposed group that demonstrate a defined effect, and the dose. A dose-effect relationship describes the relationship between the severity of a health effect and the dose.

A hierarchy of effects on health can be identified for most hazards, ranging from acute illness and death to chronic and lingering illnesses, from minor and temporary ailments to temporary behavioral or physiological changes, as shown in Table 7.5.

Table 7.5: Range of Effects on Human Health Due to Environmental Exposure

- š Premature death of many individuals
- š Premature death of any individual
- š Sever acute illness or major disability
- š Chronic debilitating disease
- š Minor disability
- š Temporary minor illness
- š Discomfort
- š Behavioral changes
- š Temporary emotional effects
- š Minor physiological change

Dose-response relationships are considerably different for non-carcinogens (thought to have a threshold) and carcinogens (thought to be non-threshold) as discussed further below.

7.7. Human exposure assessment

7.7.1 Options in Approach

Human exposure is defined as the opportunity for absorption into the body or action on the body as a result of coming into contact with a chemical, biological or physical agent. The various routes of exposure have already been introduced. The units of exposure to a chemical are usually concentration multiplied by time (e.g. mg/ml/hr). The term total exposure implies that an attempt is being made to take into account all exposures to the contaminant regardless of media or route of exposure.

The critical parameter with respect to health is actually the dose, since it directly identifies the amount of the contaminant

reducing exposure, as opposed to dose. Estimates can then be made of the dose, based on the exposure, various assumptions, and animal models. While such estimates often have large uncertainties, it is a more practical parameter than dose. In any case, it has to be clear that measuring exposure, it is a more practical parameter than dose. In any case, it has to be clear that measuring exposure, not concentration, is the critical parameter since it is more directly related to health

marker of effect, or a marker of susceptibility. Exposure markers are of greatest interest to regulators and those charged with the need to control exposures. Clinicians are generally more interested in markers of health or susceptibility. The marker of most interest to epidemiologists depends on the nature of the epidemiological study.

7.7.2. Personal Exposure Monitoring

Personal air monitoring devices provide direct measurements of concentrations of air contaminants in the breathing zone of an individual. Generally, samplers worn by subjects record time-integrated concentrations or they collect time-integrated samples. These may be devices that read concentrations directly (in the case of the former) or ones that require lab analysis (as is generally the case in the latter). Samplers may be either active (requiring a pump to move air) or passive (require no pump and collect the airborne contaminant by diffusion).

With respect to waterborne contaminants, a direct measurement entails sampling from the water source, like a drinking tap, or from the water actually drunk. With respect to food, duplicate meals are analyzed. In this method, an individual must collect a second portion of everything consumed. This duplicate meal is then homogenized and analyzed for the compounds of interest.

Direct measurements of skin exposures in an occupational environment have been established by attaching patches on the skin. After a working day, the patches can be removed, extracted and analyzed. The effectiveness of using gloves to protect skin exposure can be established in a comparable way. Cotton gloves worm underneath latex gloves can be analyzed for specific chemical agents after handling. The results would indicate whether and to what extent the compound of interest can penetrate the gloves. Based on these results, it can be indicated how frequently gloves should be changed in order to prevent exposure.

7.7.3..Biological Monitoring

In biological monitoring, the contaminant of interest, its metabolite or the product of interaction between it and some target molecule or cell is measured in the relevant body tissue. If lead is the contaminant of interest, for example, area sampling can be conducted to determine the operations associated with the greatest lead concentration; personal air monitoring for lead exposure may be conducted; blood lead levels may be drawn on exposed workers to measure dose; or a marker of effect such as free erythrocyte protoporphyrin (FEP) may be evaluated.

Biological monitoring for susceptibility markers is a highly controversial area. Markers of susceptibility may relate to induced variations in absorption, metabolism, and response to environmental agents. For example, measurement of airway reactivity to inhaled broncho-constrictors can be used as a marker of susceptibility to asthma.

Examples of some biological markers of exposure are shown

Table 7.6: Examples of Useful Markers of Exposure

Substance	Biological Marker
Carbon Monoxide	COHb in blood
Lead	Pb in blood
Pentachlorophenol (PCP)	PCP in urine
Alcoholic Beverages	Ethanol in exhaled breath
Volatile Organics (VOCs)	VOCs in exhaled breath

7.7.4. The Indirect Approaches to Estimation of Exposure

Exposure assessment surveys, whether they be questionnaires, telephone interviews or measurements, usually attempt to obtain information in four areas: demographic profile, health status, environmental factors and time-activity. There are three general approaches for obtaining time-activity information. One is called the estimation approach, in which an estimate is made of the amount of time spent by study participants in various activities during the time period of interest. The second approach uses time activity diaries in which participants are asked to

during the study period. The third approach is the *observational* approach in which the participants are monitored by outside observers.

- 1. $1000 \text{ liters} = 1 \text{ m}^3$
- 2. The first value represents straight tap water only, while the second includes tap water-based beverages such as tea, coffee and reconstituted soft drinks. Exclusively breast-fed infants (BF) do not require additional liquids. Estimates for non-breast-fed infants (NBF) are based on volume consumed as drinking-water, and on drinking of 750ml/day of formula made from powdered formula and tap water for total drinking-water.

7.7.5. Estimating Inhalation Exposure

With respect to air measurements, outdoor measurements have been an integral part of environmental monitoring in many countries for several decades. However, indoor air has been ignored until recently. Thus, while many air pollutants are at higher concentrations indoors than outside, indoor air quality monitoring procedures are less well-developed. This will be discussed further in subsequent chapters. In order to estimate an inhalation dose, an estimate of the amount of air a person breathes in a day is required. (Standard values for the amount of ai5 0 TD(y)TD.D-.m]TJa Tw[(hdarrious aghigh)5 g.8(u)5.3amr purd

Box 3.6 utilizes the above information in a concrete example.

BOX 3.6

Estimating Lead Intake Via Inhalation by a Child

Task: estimate the cumulative dose of inhaled lead for an 11-year-old child who has been exposed for two hours per day every day since birth, to lead in outdoor air at a concentration of 8x10-5 mg/m³. Exposure ended at age 12 when the family moved to another area.

The cumulative dose is calculated as follows:

The inhalation rate (IR) of contaminated air is a fraction of the total air breathed, in this case 2 hours of exposure /day x total daily amount of air inhaled. The total daily amount of air inhaled changes as a child grows (see Table 3.11). Multiplying each of these values by 2/24 (0.083) gives an IR of 0.166m³

estimate the population linked to the areas in order to construct a sampling frame.

If the target population consists only of people with specific characteristics, lists of these people may be available. For example, if the target population consists of lactating mothers, clinics in the area may be able to provide lists of mothers who have recently had deliveries. If available lists do not provide nearly complete coverage of the target population, samples from the lists must be supplemented with samples from other, possibly less efficient, frames that provide more complete coverage of the target population (see UNEP/WHO, 1993).

7.7.7. Principles of Environmental Sampling

The potential for errors in environmental exposure assessment is large. Errors may occur with respect to the representative ness of sampling sites, the method of sample collection, the analytic procedure, and data handling.

The representative error refers to whether the sample collected represents the average concentration in the media under study. For example, an outdoor monitor on the roof of a multistoried building may not yield the concentration data needed to estimate average community air exposure. Even if sampling is conducted at a reasonable site, there is always a question as to how representative it is of exposure to residents at different times or when wind blows from different

directions. Portable sampling in various directions and at

Quality assurance programs have therefore been developed and much international guidance has been provided on this subject. Procedures include the use of standard reference materials when calibrating instruments, keeping the line voltage and temperature constant, conducting duplicate analyses of some of the collected samples, etc. Sometimes the above activities are considered quality control operational activities. Quality assurance refers to activities that are conducted after the data have been collected, to determine the precision and accuracy of the data, and to sort out improper data. This uses methods such as interlaboratory comparisons, using different analytical methods to analyze the same sample, the use of various statistical procedures to highlight bad data or extreme values, etc. the overall term quality assurance generally includes both quality assurance and quality control activities.

7.7.8. Ensuring Adequate Sample Size

Determining an appropriate sample size requires balancing precision and cost constraints. Guidelines for calculating sample sizes needed for accurate estimates are available in many textbooks and other WHO publications including UNEP/WHO 1993. Even if the final sample sizes are determined primarily by cost constraints, rather than for desired precision, it is essential to calculate the precision that

expected for important hypothesis tests. There must, however, be minimum standards for reliability of inferences. In general, a sample size of 50 is the minimum acceptable for human exposure monitoring studies, with a range of 250 or more people considered desirable. In preparing reports based on sampling with borderline or minimal sample sizes, it is essential for the problems regarding inferences to the target population to be discussed. These include: (a) Unreliable point estimates, (b) Unreliable estimates of precision, and (c) lack of normality for interval estimates and hypothesis tests (see UNEP/WHO 1993 for greater detail).

7.8. Health risk characterization

7.8.1. General Approach Summarized

Risk characterization synthesized the first three components of the risk assessment process: hazard identification, doseresponse assessment and exposure assessment, and estimates the incidence and severity of potential adverse effects. The major assumptions, scientific judgments and uncertainties should be identified to fully understand the

Table 7.9: Consecutive steps in Health Risk
Characterization

- Exposure = pollutant concentration/ exposure duration (or it is directly measured by integrated sampling).
- Dose = Exposure (1) x dosimetery factors (absorption rate, inhalation rate, etc.) body weight or surface area.
- Lifetime individual risk = Dose (2) x risk characterization factor (carcinogenic potency, noncarcinogenic threshold [e.g. NOEL] or severity [e.g. NOAEL], with
- Risk to exposed population = Individual risk (3) x number in exposed population (this should take into consideration age, and other susceptibility factors, population activities, etc.).

7.9. Health in environmental impact assessment (EIA)

A part from health risk assessment in field situations it is also important to consider potential health effects of projects or activities which are planned for the future. However, health effects have often received inadequate attention during the formulation of development policies and planning of projects. In many countries where procedures exist to assess

environmental impacts, only (or predominantly) impacts on the biophysical environment are assessed. When these parameters conform to the legally established environmental standards it is assumed that human health effects are not likely to occur.

In principle the assessment of adverse health impacts follows an approach similar to the risk assessment frame work discussed in the previous sections of this chapter. First, potential hazards associated with the project which require further investigation have to be identified. Subsequently, emissions have to be calculated or estimated using technological specifications of the project. Based on these data, emission concentrations, exposure and total dose should be calculated using mathematical models which have been developed specifically for these purposes.

As an environmental impact assessment (EIA) is a practical process, it is not generally possible to undertake additional primary research simultaneously. Consequently, conclusions must usually be based on currently accepted scientific knowledge. Furthermore, no actual measurements can be performed during the preparation stage of a project, other than baseline assessments or measurements from pilot projects. Therefore, extrapolation of data regarding emissions, exposures and (if available) health effects from similar projects can be extremely useful. These extrapolations from

one situation to another with different geographical and demographic features, as well as exposure characteristics, usually require a number of assumptions, and therefore again specific expertise is also required.

The health component of environmental impact assessments should incorporate more than the best scientific information available. It should draw upon community-based information and traditional knowledge of native peoples and others in the community. And it should recognize that many projects have beneficial as well as adverse effects on health and well being. By creating jobs and providing other economic benefits that contribute to a better standard of living, health may be greatly improved because of the project in question. As noted in chapter 1, economic well-being has been repeatedly linked with longevity and other indicators of health, because, among other reasons, people with adequate income can afford to eat balanced diets and live healthy lifestyles. Adverse effects on health may be disproportionately experienced by people who do not share in a project's benefits. Thus the health components of the EIA should assess who will benefit and who may experience adverse effects. If potential adverse effects are identified, recommendations for mitigation and follow-up measures should be included in the environmental impact statement (EIS) which the project's proponent is required to do. EIAs may also consider alternatives to the project, including the potential effects on health of not allowing the project to proceed. Although there may be jurisdictional considerations regarding which government department is responsible for occupational versus public health in some countries, both components are essential to ascertain the potential benefits and adverse effects of a proposal.

7.10. Exercise questions

- 1. List and describe Environmental factors of human exposures?
- 2. What are the advantages and disadvantages of environmental and biological Monitoring respectively?
- 3. Describe the concept of EIA?

CHAPTER EIGHT SAMPLING AND ANALYSIS

8.1. Learning Objective

After the completion of this chapter, the student will be able to:

- Describe the importance of Air as the basic health requirement of human life
- 2. Define what air pollution means and other related terms
- 3. Enumerate different types of air pollutants
- 4. List physical forms of pollutants

8.2. Introduction

Some air pollution problems, such as foul odors, are relatively straightforward to manage and can be dealt with as a public An air shed is a space, such as a valley, basin, or plain, within which air mixes relatively freely but beyond which movement is relatively slower, and typically depends on winds. In order to improve air quality within an air shed it is necessary to control all the sources within the air shed.

In order to set targets for the control of air pollution, it is necessary to set standards or guidelines. The word standard

this is usually done at the state level. Some states have set stricter environmental standards. Canada, on the other hand, has guidelines that are recommended by a federal department, Health Canada, but any action to be taken is the responsibility of the provinces, which may set local standards. On paper, Canada's guidelines are much stricter, but they must be understood to be targets, not rules. Because air quality in Canada is not generally as polluted (with some local exceptions), the use of guidelines allows greater flexibility to local authorities to deal with the problem. If the pollution problem were more severe, the adoption of national air quality standards could permit tighter legal enforcement and stricter regulation across the country. Table 11 presents the revised Air Quality Guidelines for Europe recommended by the WHO.

Table 8.3: WHO Air Quality Guidelines for Europe, Revised 1994

Compound	Guideline	Value	Averaging Time
Ozone	120>g/m³	(0.06 ppm)	8 hr
Nitrogen dioxide	200 > g/m ³	(0.11 ppm)	1 hr
	40 to 50>g/m ³	(0.021 to 0.026 ppm)) Annual
Sulfur dioxide	500 >g/m ³	(0.175 ppm)	10 min
	125 > g/m ³		

health effects or visibility. In recent years, standards have been increasingly set on the basis of human health effects, after an exhaustive review of scientific studies. In order to protect the health of the public, air quality standards today are often set by conducting a risk assessment that predicts what the expected number of cases of cancer or of death might be at a given level of air pollution. When the risk appears to be

8.4. Exercise questions

- 1. Explain the importance of having guidelines and standards.
- 2. Describe what guideline means.
- 3. Describe what standards means.
- 4. Explain the difference between guidelines and standards.

CHAPTER NINE AIR POLLUTION PREVENTION AND CONTROL

9.1. Learning Objective

After the completion of this chapter, the student will be able to:

- Define what air pollution prevention and control means
- 2. Describe the importance of Air as the basic health requirement of human life
- Enumerate different types of air pollution prevention methods

9.2. Introduction to the course

The reduction of energy consumption, use of nonconventional sources for energy and natural source of energy and maintenance green belts is the key to manage air pollution problems. The measures for prevention and control of air pollution are given below:-

 Increasing the community awareness about air pollution, sources and effects of pollution and how to avoid them.

- Substitution measures- The current industrial or combusting practices which produce pollutants are replaced by non-hazardous or less hazardous process. Substitute electric power in place of fossil fuels, coal substituted by the biogas plants. Use of solar energy and hydraulic operations for industrial purposes should be encouraged. The use of solar energy and hydraulic operations for industrial purposes should be encouraged. The use of smokeless churlish in place of age old churlish dramatically improves indoor air quality.
- Containment action: Escape of pollutants in the air from the industrial operations can be controlled by operating local exhaust ventilation, trapping and then the disposal of pollutants.
- Dilution: Maintenance of green belt between and around the industries, in between industries and civilian habitat filter a lot of air pollutants and maintains air quality.
- Legislative action: The factories act and smoke
 Nuisance Act lay down measures for height of
 chimney stacks, use of arrestors, for industrial areas.
 The lead levels in petrol can be minimized or leadless
 patrol can be made available through governmental
 regulatory approach.

• Active community involvement: Regular maintenance of automobile vehicles; use of arrestors to the exhaust from automobiles; complete combustion of coke, coal and wood; screening of windows; use of LPG gas; proper effective ventilation in home and at work place, use of solar and biogas energy, community action for collection and final disposal of refuse and solid wastes, maintenance of green belts, forbidding tobacco smoking, use of smokeless churlish, maintenance public places; cleanliness of streets and open areas and a lot many actions can be undertaken for control and prevention of air pollution.

9.3 Control of Ambient Air Pollution

Control of emissions at each source is the key to managing air quality, but transportation policy, energy policy (such as the choice of fuels), and sitting/ zoning of facilities that may emit pollution all play a critical role. A major element in the success of air pollution control is the degree of authority that can be exerted by the government agency that has this responsibility. The ability to close or shut down a plant is the ultimate tool for enforcement agencies, but the ability to fine, bring lawsuits, and to prosecute offenders is just as important. Often just the threat of such action motivates the management of a plant to cooperate and to correct the problem.

Emissions standards (rules about how much pollution a particular source may emit to the atmosphere) require periodic inspection and regular monitoring to be effective. These are generally easier to enforce for stationary sources, where equipment can be set up on a permanent basis and the pollution control apparatus can be inspected directly. The source or facility may require a permit from the government to operate or may be required to register and to provide regular reports on the pollution it has generated.

Generally, emissions standards for individual factories, power plants, or other stationary sources are allocated an allowable level of emissions based on their past performance and share of contribution to the regional air shed. They must not exceed this allowable level of emissions or they will receive a citation and must pay a fine. (In practice, the fine must be high enough to deter violations and not to be just another cost of doing business.) If they are repeat violators, their permit to operate can be suspended if the law allows.

In some jurisdictions, the entire plant is considered a single source; if engineers can reduce emissions in one part of the plant, they are allowed to build new facilities that increase emissions in another part or to build a new addition to the plant that may generate new emissions. The overall level of emissions from the entire plant must not increase, however. This is called the Bubble concept, because the plant is

thought of as being enclosed in a bubble and the air and the air quality in the bubble cannot be allowed to deteriorate.

Mobile sources are difficult to monitor, however, many jurisdictions require regular vehicle inspections to ensure that emissions from each truck or automobile are within

filter dust collect or operating under ideal conditions can not remove all dusts particles to satisfy the PEL (less than one percent quartz/ 10 mg./cubic meter nuisance dust.

4. Respirable usage

Since most dusts are hazardous to the lungs, respirators are a common method of primary or secondary protection. Respirators are appropriate as a primary control during intermittent maintenance or cleaning activities when fixed engineering controls may not be feasible. Respirators can also be used as supplement to good engineering and work practice control for dusts to increase employee protection and comfort.

To be effective respirators must be matched to the type of particulate hazard present. The critical exposure factors mentioned above (type of dust, length of exposure, dust size, concentration etc.) determine the degree of hazard and the type of respirators that should be employed.

Box 3

Motor vehicle Air Pollution: Health Effects and Control Strategies

Studies of human exposures to air pollution from motor vehicles have revealed the following:

- š Concentrations of some air pollutants inside motor vehicles and along roadsides are typically higher than those recorded simultaneously at fixed-side monitors.
- š Exposures tend to be higher inside automobiles than in buses and other vehicles used in public transit.
- Š Priority lanes used to afford speed advantages to buses and car pools tend to reduce air pollutant exposures.
- Š Concentrations of air pollutants in enclosed settings are similar to outdoor concentrations in the absence of indoor sources, but tend to lag behind the peak concentrations observed outdoors. (A notable exception is commercial buildings attached to inadequately ventilated parking garages.)
- Š Concentrations of motor vehicle air pollutants decline with greater distance from the road, suggesting that passengers and vehicles are at greatest risk, followed by pedestrians and street merchants along roadsides, and then the general urban population.

Motor vehicle emissions may be reduced by: 1) controlling vehicle performance, and 2) altering fuel composition. With respect to vehicle performance, this can be controlled by ensuring that vehicles are designed and

built to meet standards. It is also necessary that they be properly maintained. Proper maintenance, in turn, can be promoted by providing incentives to car owners to obtain proper maintenance and by marketplace incentives. Requiring maintenance through a mandatory inspection and maintenance programme is considered by many to be the most effective incentive for car owners.

Fuel composition may be controlled as a direct means of controlling emissions, 01 Cg. d bucg emth6()e leadontrotiv6.5()] prlead asgaso6(l)11

complicated equipment needed for air quality monitoring and who can interpret the results. A permitting or registration system is needed for enforcing emissions standards. Public

- Improving house design and construction of proper ventilation
- 3 Health Education
- 3 Improving standard of living

Ventilation: this might be through opening windows, doors, or using fans with or without washing or aid, so that there is a considerable air interchange. It is believed that with in practical limits of air interchange, there is not apparent effect up on disease incidence. Practically this method can not be sued in hospitals or nurseries, unites and otherwise the incoming air is flattered and conditioned

9.4. Exercise question

Study Exercise

Air quality management may involve controlling sources of emissions from industry, transportation, and homes. What effect on air quality may be expected from national transportation policies that favor automotive transportation over mass transit? What may be expected from a national energy policy that favors the burning of fossil fuels over hydroelectric or nuclear energy? Does the economic base and structure of the community have any implications for air quality in the region? What role does city and regional planning play in influencing air quality? In the region? What role does city and regional planning play in influencing air quality? Use your home community as an example of these issues, and then compare the situation in another city, town, or village in your country. A number of initiatives and suggestions for better management of air resources have been discussed in this chapter. Try to develop other initiatives that could be used to promote air quality conservation. These could be economic, social, legal or physical in nature.

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APPENDIX

Annex-1

Weather- man wind measuring reports system

Beaufort numbers	Map symbol for wind speed and direction	Speed M.P.H	Description	Specification
0	0		calm	Smoke rises vertically
1		1 to 3	Light air	Wind direction shown by
				drift of smoke
2		4 to 7	Slight breeze	Wind flet on face; leaves
				rustle; flag stirs
3		8 to 10	Gentel	Leaves & twigs in constant
			breeze	motion; wind extends light
				flags
1				

4

8	0////	39 to 46	Fresh Gale	Leaves & twigs in constant motion; wind extends light flags
9	0////	47 to 54	Strong gale	Slight damage to house
10	0////	55 to 63	Whole gale	Trees uprooted; much damage to house
11	0_/////	64 to 75	Storm	Widespread damage
12	0_/////	Over 75	Hurricanes	Excessive damage

Annex-2

Some questions worth asking about fuel, cooking and ventilation

1. Type of fuel

- Biomass (wood, agriculture waste, grass, leaves, etc manure, dried dung)
- Biogas
- Wool Alco hole
- Fossil fuel (coal, coke, oil, kerosene, natural gas, propane)

2. Type of stove

- Stone tripod (hole in the ground, clay and metal)

3. Location

Inside one room hut (special indoor cooking and outdoor)

4. Uses

- Cooking only (cooking and heating)

5. Ventilation

- None (windows, hole in roof and chimney)

6. Fuel gathering

- Women (women and children, men)

Annes-3

INDOOR AIR SAMPLING PROCEDURE

- I. Gravimetric sampling technique
 - Total suspended particulate matter will be measured by air suction foot pump.
 - Measurement is taken at a height > 1 meter roughly

- Uncover the plate in its chosen position for the measured period of time, and then at once replace its lid. It is generally suitable to expose plates on tables with legs about 1m above the ground.
- Incubate the plates aerobically for 24 to 49 hrs at 37°C.
- Count the colonies, preferably with the use of colony counter (plate microscope) to detect the smallest ones.
- Express the results as the number of bacteria carrying particles setting on a given area in a given period of time.