CHEMICAL CHAR. _____ _ ___ ____ COLLECTED AT
SELECTED SITES AROUND KUANTAN

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# ABSTRACT

This study was conducted to determine the composition of rainwater at five selected station in the area between Gambang to Kuantan in Pahang, from end of September 2011 until late November 2011. The samples were collected randomly using polyethylene open container and the parameters measured were the anions ($F^-$, $Cl^-$, $NO_3^-$, $PO_4^{2-}$ and $SO_4^{2-}$), cations ($K^+$, $Mg^{2+}$, $Na^+$, $Ca^{2+}$, and $NH_4^+$) and trace metal include Lead(Pb), Cadmium(Cd), Iron(Fe), Manganese(Mn), Copper(Cu), and Chromium(Cr). For the rainwater samples, the ionic species was analyzed using Ion Exchange Chromatography while Atomic Absorption Spectrometer was used to analyzed trace metal species. The pH value of the rainwater were determined. As the result from this study, for station 1 located at Felda Lepar Hilir, the dominant cation was calcium with concentration 1.206±0.119mg/L and the dominant anion was nitrate ion with concentration (1.224±0.304mg/L. The pH obtained at station 1 was 5.51±0.562. for Station 2 located at UMP, the dominant cation was calcium with concentration 1.856±3.092mg/L and the dominant anion was sulphate ion with concentration 1.220±0.632mg/L. The pH obtained for station 2 was 5.34±0.22. For Station 3, the dominant cation was calcium with concentration 0.833±0.467mg/L and the dominant anion was chloride with concentration 0.826±1.233mg/L. The pH obtained for this station was 6.05±0.56. For station 4 located at Kuantan Royal Malaysian Air Force base, the dominant cation was calcium with concentration 1.816±0.767mg/L and the dominant anion was nitrate with concentration 1.692±0.876mg/L. The pH obtained from this sampling site was 6.43±0.33. For the last station which is located at Kuantan city. The dominant cation was calcium with concentration 1.544±0.311mg/L and the dominant anion was sulphate with concentration 1.244±0.606mg/L. The pH obtained for this sampling site was 6.65±0.04. For the determination of the trace metal species, trace metal species was not detected since the value obtained was below the limit of detection. Hence can be conclude that chemical composition of rainwater depending on the geographical location and main activity of each sampling location. Hence can be conclude that chemical compostion of rainwater is depending on the main activity at the sampling area.

# ABSTRAK

Kajian ini telah dijalankan untuk mengenalpasti komposisi air hujan di lima tempat terpilih diantara kawasan Gambang ke Kuantan dari penghujung September 2011 sehingga akhir November 2011. Sampel dikutip secara rawak menggunakan bekas polyethylene terbuka dan parameter yang disukat merupakan anion ($F^-$, $Cl^-$, $NO_3^-$, $PO_4^{2-}$ and $SO_4^{2-}$), kations ($K^+$, $Mg^{2+}$, $Na^+$, $Ca^{2+}$, and $NH_4^+$) and logam termasuklah Lead(Pb), Cadmium(Cd), Iron(Fe), Manganese(Mn), Copper(Cu), and Chromium(Cr). Nilai pH air hujan termasuklah kepekatan pepejal terlarut dikenalpasti. Bagi station 1 terletak di Felda Lepar Hilir, kation yang mendominasi adalah calcium dengan kepekatan ($1.206\pm0.119$)mg/L dan anion yang mendominasi adalah ion nitrate dengan kepekatan ($1.224\pm0.304$)mg/L. pH yg diperolehi dari station 1 adalah $5.51\pm0.562$. Bagi Station 2 terletak di UMP, cation yang mendominasi adalah calcium dengan kepekatan ($1.856\pm3.092$) dan anion yang mendominasi adalah ion sulphate dengan kepekatan ($1.220\pm0.632$)mg/L. pH doperoleh dari station 2 adalah $5.34\pm0.22$. Bagi Station 3, cation yang mendominasi adalah calcium dengan kepekatan ($0.833\pm0.467$)mg/L dan anion yang mendominasi adalah chloride dengan kepekatan ($0.826\pm1.233$)mg/L. pH doperolehi dari station ini adalah $6.05\pm0.56$. Bagi station 4 yang terletak di Lapangan tentera udara Diraja Malaysia Kuantan, cation yang mendominasi adalah calcium dengan kepekatan ($1.816\pm0.767$)mg/L dan anion yang mendominasi adalah nitrate dengan kepekatan ($1.692\pm0.876$)mg/L. pH yang diperoleh dari station ini adalah $6.43\pm0.33$. Bagi station terakhir yang terletak di Bandar Kuantan, cation yang mendominasi adalah calcium dengan kepekatan ($1.544\pm0.311$)mg/L dan anion yang mendominasi adalah sulphate dengan kepekatan ($1.244\pm0.606$)mg/L. pH diperoleh bagi station ini adalah. Spesis ion di dalam air hujan dianalisi dengan menggunakan Ion Kromatografi manakala logam yg dikesan dianalisis dengan menggunakan dianalisis dengan menggunakan Penyerap Spectrophotometer Atom. Walaubagaimanapun, kesemue logam yang dianalisis menunjukkan kepekatan dibawah paras pengesanan. Maka dapat disimpulkan bahawa komposisi kimia air hujan adalah bergantung kepada kegiatan utama bagi tempat sampel diambil.

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# CHAPTER 1

# INTRODUCTION

## 1.1    BACKGROUND OF STUDY

Rainwater plays an important role in scavenging soluble components from the atmosphere and helps us to understand the relative contribution of different sources of atmospheric pollutants (Kulshrestha et al., 2003). The composition of rainwater actually reflects the composition of the atmosphere through which it falls. The study of composition of wet deposition encourages evaluating the relative importance of the different sources for gases and particularly mattering (Demirak et al., 2006). Wet deposition is an efficiently scavenging process for pollutants present in the atmosphere both in the gas and aerosol phases and provides a path for essential nutrients to reach terrestrial and aquatic ecosystems. Wet deposition has several harmful effects on various environmental compartments, with acidification as a major concern (Brimblecombe, 2001)

The chemical composition of rain is influenced by both natural and anthropic sources, and is the result of the incorporation of particles and air pollutants into cloud droplets. These two sources are difficult to study experimentally, but the determination of the chemical composition of rain, together with the analysis of meteorological conditioning can aid in understanding the causes of rain acidification (Sanusi et al., 1995)

Wet precipitation constituents are the most effective scavenging factor removing particulate and organic and in organic gaseous pollutants from the atmosphere. The scavenging of the atmospheric pollutants affects the chemical composition and the pH of rainwater. The acidic precipitation is primarily caused by incorporation of anthropogenic sources such as $SO_2$, $NO_x$ and other acid precursors (Das et al., 2005; Migliavacca et al., 2005). On the other hand, neutralization of acidity in rainwater can be either due to CaCO3 in airborne dust (Munger, 1982; Al-Momani et al., 1995) and or ammonia released from industrial, agricultural and other natural sources (Schuurkes et al., 1988).

## 1.2 PROBLEM STATEMENTS

### 1.2.1 Acid Rain

Acid rain has likely been a problem at least since the beginning of the Industrial Revolution. In recent decades, however, acid rain has gained more and more attention; today, it is a major global environmental problem affecting all industrial countries (Botkin et al., 2007).

Acid rain is precipitation in which the pH is below 5.6. The pH of the solution is an expression of relative acidity and alkalinity. All rainfall is slightly acidic; water reacts with atmospheric carbon dioxide to produce weak carbonic acid. Thus pure rainfall has a pH of about 5.6 (Botkin et al., 2007).

Acids result from natural causes, such as vegetation, volcanoes, and lightning, and from human activities, such as the burning of coal and use of the internal combustion engine. These combustion processes produce sulfur dioxide ($SO_2$) and oxides of nitrogen ($NO_x$). Oxidizing agent such as ozone, hydroxide ions, or hydrogen peroxide, along with water, are necessary to convert the sulfur dioxide or nitrogen oxides to sulfuric or nitric acid (Enger et al., 2010)

Acid rain can cause damage in several ways. Buildings and monuments are often made from materials that contain limestone (calcium carbonate, $CaCO_3$), because limestone is relatively soft and easy to work. Sulfuric acid ($H_2SO_4$), a major component of acid rain, converts limestone to gypsum ($CaSO_4$), which is more soluble than calcium carbonate and is eroded over many years of contact with acid rain (Enger et al., 2010)

## 1.2.2 Trace Metals

The study of trace metals in wet and dry precipitation has increased in the last decades because of their adverse environmental and human health effects. Some metals such as Pb, Cd and Hg, among others, accumulate in the biosphere and may be toxic to living systems (Galloway et al., 1982; Barrie et al., 1987). Anthropogenic sources have substantially increased trace metal concentrations in atmospheric deposition. In addition, acid precipitation favors the dissolution of many trace metals, which enhances their bioavailability. If the concentrations are too high, many of the trace metals can harm human health through the consumption of drinking water and/or aquatic organisms. Trace metals from precipitation can also accumulate in surface waters and soils where they may cause harmful effects to aquatic life and forest ecosystems (Howard et al., 2004).

Trace metals are deposited by rain, snow and dry fallout. Rainout and washout are the predominant processes of deposition by rain (Seinfeld and Pandis, 1998). Usually over 80% of wet deposited trace metals are dissolved in rainwater, reaching the vegetation canopy in the most favorable form for uptake (Valenta et al., 1986). Atmospheric transport and deposition processes are important in the global recycling of trace metals.

## 1.3    PROJECT OBJECTIVES

The objective of this study is to determine the chemical composition of rainwater at selected sites around Kuantan. However, to be specific, the objectives of this study are:-

i)    To determine the composition of cations and anions composition inside the rainwater at selected sites around Kuantan, and

ii)   To determine the composition of traced metals inside the rainwater at selected sites around Kuantan

## 1.4    SCOPE OF STUDY

The aim of this study is to understand the chemical composition of rainwater collected from five sampling sites around Kuantan, Pahang. The sampling sites covered places with different land use and daily activities. Ten major anions and cations ($F^-$, $Cl^-$, $NO_3^-$, $SO_4^{2-}$, $PO_4^{3-}$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, $NH_4^+$) and trace metal (Mn, Fe, Co, Pb, Cu, Cd) that are contain in the rainwater samples was analyzed using IEC and AAS. The rainwater sample also was analyzed for temperature and pH value.

The sample was taken from five different places and these places have different activities each. The rationale of this proposed research project is to determine the chemical composition of rainwater at selected site around Kuantan. The results of this research would provide a background data about the chemical composition of rainwater in the studied area.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 RAINWATER

In hydrological cycle, there is movement of water. From the oceans to the atmosphere by evaporation and from atmosphere to oceans and land by precipitation, from land to oceans by runoff and from streams and rivers and from land to atmosphere by evaporation. This cycle is driven by solar energy (Ahluwalia et al., 2008)

During the precipitation, rainwater contaminated by certain industries are expected to show dissolved signatures of contaminants because of water-or cloud-particle interaction. This has been explained by the study of the chemical composition of rainwater in a tropical urban area of northern area that define Pollutants like gases and particles present in atmosphere may be dissolved and/or transported by the rain water and brought to the ground. Rainfall is one of the most effective ways of removing atmospheric pollutants (Spanos et al., 2002)

It the previous study, it is found that rainwater composition plays an important role in scavenging soluble components from the atmosphere and helps us to understand the relative contribution of different sources of atmospheric pollutants. The composition of rainwater actually reflects the composition of the atmosphere through which it falls. The study of composition of wet deposition encourages evaluating the relative importance of the different sources for gases and particularly mattering. Wet precipitation constituents are the most effective scavenging factor removing particulate

and organic and in organic gaseous pollutants from the atmosphere (Kulshretha et al., 2003).

## 2.2 ACID RAIN

Acid precipitation refers to any precipitation-rain, fog, mist, or snow that is more acidic than usual. Because dry acidic particles are also found in the atmosphere, the combination of precipitation and dry-particles fallout is called acid deposition (Wright and Nebel, 2008). To understand the full extent of the problem, first we must understand some principles about acids and how we measure their concentration (Wright and Nebel, 2008).

### 2.2.1 Acid and Bases

Acidic properties (e.g., a sour taste and corrosiveness) are due to presence of hydrogen ions ($H^+$ a hydrogen atom without its electron), which are highly reactive. Therefore, an acid is any chemical that releases hydrogen ions when dissolved in water. The chemical formulas of a few common acids are shown in Table 2.1. Note that all of them ionize − that is, their components separate − to give hydrogen ions plus a negative ion. The higher the concentration of hydrogen ions in a solution, the more acidic is the solution (Wright and Nebel, 2008).

**Table 2.1:** Chemical formulas of a few common acids

| Acid | Formula | H$^+$ Ion(s) | Plus | Negative Ion | |
| --- | --- | --- | --- | --- | --- |
| | | | | Ion | Name |
| Hydrochloric acid | HCl | $\longrightarrow$ | H$^+$ | + | Cl$^-$ | Chloride |
| Sulfuric acid | H$_2$SO$_4$ | $\longrightarrow$ | 2H$^+$ | + | SO$_4^{2-}$ | Sulfate |
| Nitric acid | HNO$_3$ | $\longrightarrow$ | H$^+$ | + | NO$_3^-$ | Nitrate |
| Phosphoric acid | H$_3$PO$_4$ | $\longrightarrow$ | 3H$^+$ | + | PO$_4^{3-}$ | Phosphate |
| Acetic acid | CH$_3$COOH | $\longrightarrow$ | H$^+$ | + | CH$_3$COO$^-$ | Acetate |
| Carbonic acid | H$_2$CO$_3$ | $\longrightarrow$ | 2H$^+$ | + | HCO$_3^-$ | Bicarbonate |

A base is any chemical that releases hydroxide ions (OH$^-$, oxygen-hydrogen groups with an extra electron) when dissolved in water. (Table 2.2) The bitter taste and caustic properties of all alkaline, or basic, solutions are due to the presence of hydroxide ions (Wright and Nebel, 2008). The concentration of hydrogen ions is expressed as pH. The pH scale goes from 0 (highly acidic) through 7 (neutral) to 14 (highly basic) (Wright and Nebel, 2008).

**Table 2.2:** A base in any chemical that releases hydroxide ions

| Base | Formula | OH$^-$ Ion(s) | Plus | Positive Ion | |
| --- | --- | --- | --- | --- | --- |
| | | | | Ion | Name |
| Sodium hydroxide | NaOH | $\longrightarrow$ | OH$^-$ | + | Na$^+$ | Sodium |
| Potassium hydroxide | H$_2$SO$_4$ | $\longrightarrow$ | 2H$^+$ | + | K$^+$ | Potassium |
| Calcium hydroxide | HNO$_3$ | $\longrightarrow$ | H$^+$ | + | Ca$^{2+}$ | Calcium |
| Ammonium hydroxide | NH$_4$OH | $\longrightarrow$ | 4H$^+$ | + | NH$_4^+$ | Ammonium |

## 2.2.2  Extent and Potency of Acid Precipitation

In the absence of any pollution, rainfall is normally slightly acidic, with a pH of 5.6, because carbon dioxide in the air readily dissolves in and combines with water to produce an acid called carbonic acid. Acid precipitation then is any precipitation with a pH of 5.5 or less (Wright and Nebel, 2008). Unfortunately, acid precipitation is now the norm over most of the industrialized world.

## 2.2.3  Sources of acid rain

We must recognize the natural sources contribute substantial quantities of pollutants to the air: 50 to 70 million tons per year of sulfur (from volcanoes, sea spray, and microbial processes) and 30 to 40 million tons per year of nitrogen oxides (from lightning, the burning of biomass, and microbial prosesses). Anthropogenic sources are estimated at 100 to 130 million tons per year of sulfur dioxide and 60 to 70 millions (Wright and Nebel, 2008).

Burning fuels produce sulphur dioxide and nitrogen oxides, so the sources of acid deposition problem are evident. These oxides enter the troposphere in large quantities from both anthropogenic and natural sources. Once in the troposphere, they are oxidized by hydroxyl radicals to sulphuric acid and nitric acid, which dissolve readily in water or adsorb to particles and are brought down to Earth in acid deposition. This usually occurs within a week of the oxides' entering the atmosphere (Wright and Nebel, 2008).

Sulphur dioxide present in the air undergoes catalytic and photolytic oxidation to form $SO_3$ which react with moisture present in the atmosphere to produce sulfuric acid ($H_2SO_4$) (Wright and Nebel, 2008).

$$SO_2 \ + \ O_2 \ \longrightarrow \ SO_3 \qquad\qquad (2.1)$$

$$SO_3 \ + \ H_2O \ \longrightarrow \ H_2SO_4 \qquad\qquad (2.2)$$

The $NO_2$ present in the atmosphere react with rainwater or moisture in the presence of $O_2$ or $O_3$ and produces nitric acid ($HNO_3$) (Ahluwalia and Sunita, 2008).

$$4\,NO_2 \ + \ 2\,H_2O \ + \ O_2 \ \longrightarrow \ 4\,HNO_3 \qquad\qquad (2.3)$$

$$2\,NO_2 \ + \ H_2O \ + \ O_3 \ \longrightarrow \ 2\,HNO_3 \ + O_2 \qquad\qquad (2.4)$$

$H_2SO_4$ and $HNO_3$ formed as above come down the atmosphere in the form of acid rain. This damages the crops and plants and makes the soil acidic which is harmful for subsequent crops.

To be specific, below is the reaction regarding on how the oxides of sulfur which naturally occur in the atmosphere can turn into the most harmful gaseous pollutants (Ahluwalia and Sunita, 2008).

### 2.2.3.a Oxides of Sulfur

Sulfur forms two oxides which is sulfur dioxide (a primary pollutant) and sulfur trioxide (a secondary pollutant). The first oxide ($SO_2$) is important from the point of view of atmospheric pollutions (Ahluwalia and Sunita, 2008).

Sulfur dioxide ($SO_2$)

It is the most harmful gaseous pollutant. It is a colorless gas with suffocating smell. It irritates the respiratory system of animals and humans and damages lungs. Major sources of $SO_2$ in the atmosphere are as follows:

i)   Sulfur dioxide is released in the atmosphere by volcanic eruption.

ii) Both coal and oils contain sulfur as the impurity and on burning release $SO_2$ in the atmosphere.

iii) It is also produced when sulfide ores like pyrites ($FeS_2$), copper pyrites ($CuS$), copper glance ($Cu_2S$), Zinc blende ($ZnS$), galena ($PbS$) etc. are roasted in air during the metallurgy of respective metals.

iv) Large amount of $SO_2$ are released in the atmosphere from power plant, which coal and oil based, and also from oil refineries. Even plants manufacturing sulfuric acid release $SO_2$ into the atmosphere.

v) Hydrogen sulfide which is discharged into the air by natural processes is converted into $SO_2$ by oxidation in the atmosphere.

Functions of Oxides of Sulfur in the Atmosphere

In the atmosphere, sulfur dioxide react with oxygen to form sulfur trioxide ($SO_3$) by photolytic and catalytic oxidation processes (Ahluwalia and Sunita, 2008).

$$SO_2 + \tfrac{1}{2}O_2 \longrightarrow SO_3 \qquad (2.5)$$

$$SO^2 + \tfrac{1}{2}O_2 \longrightarrow SO_3 \qquad (2.6)$$

Sulphur dioxide also react photo-chemically with ozone producing sulfur trioxide.

$$SO_2 + O_3 \longrightarrow SO_3 + O_2 \qquad (2.7)$$
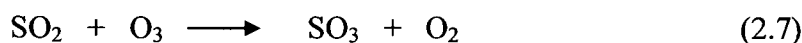
Sulphur trioxide for formed in the atmosphere reacts with water forming sulfuric acid.

$$SO_3 + H_2O \longrightarrow H_2SO_4 \qquad (2.8)$$

The sulphuric acid formed comes down to the earth as acid rain. The acid rain damages the crops and may react with ammonium salts and sodium chloride to produce sulfates.

$$H_2SO_4 + 2 NH_4Cl \longrightarrow (NH_4)_2SO_4 + 2 HCl \qquad (2.9)$$

$$H_2SO_4 + 2 NaCl \longrightarrow Na_2SO_4 + 2 HCl \qquad (2.1)$$

Sulphuric acid also damages the marble monuments (as in the case of nitric acid).

$$H_2SO_4 + CaCO_3 \longrightarrow CaSO_4 + H_2O + CO_2 \qquad (2.11)$$
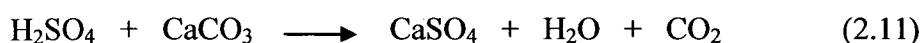
At least three major environmental episodes occur in 1930, 1948, 1952 and 1962 due to the smog conditions produced by $SO_2$ (Ahluwalia and Sunita, 2008).

Prolonged exposure of plants to even small concentrations of $SO_2$ results in decolorization of the leaves. This is because the production of chlorophyll is hampered. The colour of fabrics, leather, paper and paints fade in presence of $SO_2$ (Ahluwalia and Sunita, 2008)

The next one is regarding on $NO_2$ as pollutants. The $NO_2$ presence in the atmosphere react with rainwater or moisture in the presence of $O_2$ or $O_3$ and produces nitric acid ($HNO_3$).
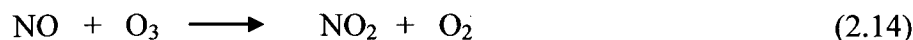
## 2.2.3.b Nitrogen Oxides

Function of Oxides of Nitrogen in the Atmosphere.

Nitrogen and oxygen combine in the atmosphere at high temperature to give nitric oxide, which is converted into nitrogen oxide by aerial oxidation (Ahluwalia and Sunita, 2008).

$$N_2 + O_2 \longrightarrow 2\,NO \tag{2.12}$$

$$2\,NO + O_2 \longrightarrow 2\,NO_2 \tag{2.13}$$

Nitric oxide can also be oxidized with ozone to give nitric oxide.

$$NO + O_3 \longrightarrow NO_2 + O_2 \tag{2.14}$$

Though nitrous oxide (which is produced by the action bacteria in the soil on nitrogen based fertilizer) is unreactive in the lower atmosphere; in the stratosphere, it gives nitric oxide and nitrogen dioxide on photolysis (Ahluwalia and Sunita, 2008).

$$N_2O + h\nu \longrightarrow NO + N \tag{2.15}$$
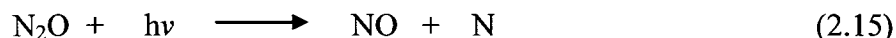
Nitrous oxide may also give nitrogen and oxygen on photolysis

$$N_2O + h\nu \longrightarrow N_2 + O \tag{2.16}$$

The free oxygen atom may react with nitrous oxide producing nitric oxide, which is subsequently oxidized to nitrogen dioxide (Ahluwalia and Sunita, 2008).

$$N_2O + O \longrightarrow 2\,NO \tag{2.17}$$

$$NO + O \longrightarrow NO_2 \tag{2.18}$$
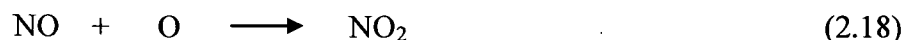
In the atmosphere, nitrogen dioxide react with water vapour producing nitric acid, which is washed down as acid rain (Ahluwalia and Sunita, 2008).

$$3\,NO_2 + H_2O \longrightarrow 2HNO_3 + NO \tag{2.19}$$
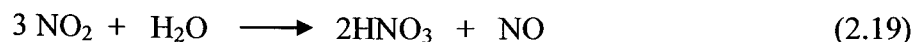
Alternatively, nitric acid may combine with ammonia (present in the atmosphere) giving ammonium nitrate.

$$NH_3 \ + \ HNO_3 \ \longrightarrow \ NH_4NO_3 \hspace{3cm} (2.20)$$

The acid rain (containing $HNO_3$) on coming in contact with marble ($CaO_3$) of the moments gives $CO_2$ gas ad calcium nitrate.

$$CaCO_3 \ + \ 2HNO_3 \ \longrightarrow \ Ca(NO_3)_2 \ + \ CO_2 \ + \ H_2O \hspace{2cm} (2.21)$$
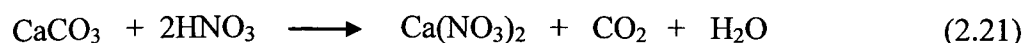
In the atmosphere, nitric oxide destroys the ozone (which absorbs harmful ultraviolet radiations coming from the sun.)

$$NO \ + \ O_3 \ \longrightarrow \ NO_2 \ + \ O_2 \hspace{3cm} (2.22)$$
$$NO_2 \ + \ O_3 \ \longrightarrow \ NO \ + \ 2 O_2 \hspace{3cm} (2.23)$$
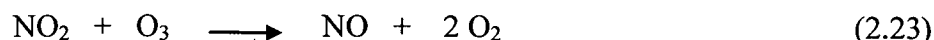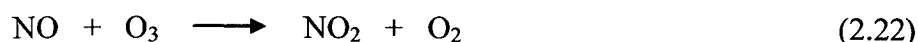
Thus, we see that both nitric oxide and nitrogen dioxide destroy ozone layer.

Being corrosive, nitrogen dioxide attack skin and corrodes teeth and causes loss appetite. It is harmful for plants and causes extensive leaf drops. It has been found that inhalation of $NO_2$ (15-30 ppm concentration) for about 2 hours, causes damage to lungs, heart, liver and kidney (Ahluwalia and Sunita, 2008).

Acid rain is rain consisting of water droplets that are unusually acidic because of atmospheric pollution - most notably the excessive amounts of sulfur and nitrogen released by cars and industrial processes. Acid rain is also called acid deposition because this term includes other forms of acidic precipitation such as snow (Ahluwalia and Sunita, 2008).

Acidic deposition occurs in two ways: wet and dry. Wet deposition is any form of precipitation that removes acids from the atmosphere and deposits them on the Earth's surface. Dry deposition polluting particles and gases stick to the ground via dust and smoke in the absence of precipitation. This form of deposition is dangerous however

because precipitation can eventually wash pollutants into streams, lakes, and rivers (Ahluwalia and Sunita, 2008).

Acidity itself is determined based on the pH level of the water droplets. pH is the scale measuring the amount of acid in the water and liquid. The pH scale ranges from 0 to 14 with lower pH being more acidic while a high pH is alkaline; seven is neutral. Normal rain water is slightly acidic and has a pH range of 5.3-6.0. Acid deposition is anything below that scale (Ahluwalia and Sunita, 2008).

### 2.2.3.c Chlorine ($Cl_2$)

Chlorine is a greenish-yellow coloured gas having disagreeable suffocating odour and is harmful even in yellow concentrations. It is a poisonous and toxic gas and causes irritation to mucus membrane. Exposure to chlorine may cause death. Chlorine is considered to be a pollutant. It is mostly released in the atmosphere by industrial processes from plastic industries, water treatment units and units engaged in the manufacture of caustic soda (Ahluwalia and Sunita, 2008).

In the atmosphere, chlorine dissolve in moisture to give hydrochloric acid and hypochlorous acid, which comes down to the earth in the form of acid rain.

$$H_2O + Cl_2 \longrightarrow HCl + HClO \tag{2.24}$$

### 2.2.3.d Carbonate

Chemically speaking, all rain is acidic with or without air pollution. This is due to the natural presence of carbon dioxide in the atmosphere which dissolves in rain drops or rain water (even moisture present in the atmosphere does the same function) to form carbonic acid (Ahluwalia and Sunita, 2008).

$$CO_2 + H_2O \longrightarrow H_2CO_3 \tag{2.25}$$
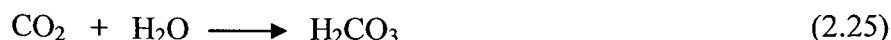
Due to above reaction, carbon dioxide can dissolve in water until the solution becomes saturated. This results in the rainwater attaining an acidic pH of 5.6. Due to this, the purest form of rain (in the absence of any of the air pollutants) reaches the earth as an acidic solution of pH 5.6. In view of above, the acid rain is described as rain whose pH is lower than 5.6 (Ahluwalia and Sunita, 2008).

## 2.2.4 Effect of acid rain

Acid rain causes extensive damage to the environment by effecting the following:

i. Vegetation

- The acid rain makes the soil acidic. This adversely affects the plants and animals. The acid rain contain $H^+$, $SO_4^{2-}$ and $NO_3^-$ ions which when added to the soil, leach the nutrients from the soil. The acid rain also damages the leaves of plants and trees. This is responsible for damaging forests and vegetation (Ahluwalia and Sunita, 2008).

ii. Fertility of Soil

- The activity of symbiotic fixing bacteria, present in the nodules of leguminous family, is inhibited. This is responsible for destroying or reducing the fertility of the soil (Ahluwalia and Sunita, 2008).

iii. Aquatic Life

- Acid rain renders the river or even ocean waters acidic, thereby, adversely effecting marine animals. Changes in pH of fresh water affect the reproduction and survival of many species of fish (Ahluwalia and Sunita, 2008).

iv. Building and Monuments

- Acid rain causes extensive damage to buildings and monuments made from marble, limestone, slate, and mortar. Limestone which is very common building material, is attacked readily.

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O \quad CO_2 \qquad (2.26)$$
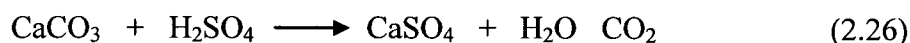
- Most of the monuments are made from marble which is mostly $CaCO_3$ and so is attacked by acid rain.

- The damage cause to the buildings and monuments by acid rain is irreversible. A most glaring example is slow degradation of Taj Mahal in Agra (UP, India). The pollutants in and near Agra arise from iron foundries, rubber manufacture, brick kilns, and oil refinery at Mathura (Ahluwalia and Sunita, 2008).

v.  Ecological Balance

- Acid rain is responsible for wiping out many bacterial and blue green algae; thereby disrupting the whole ecological balance (Ahluwalia and Sunita, 2008).

vi.  Human Health

- Acid rain has been found to be very dangerous to human health. Acidic conditions can play havoc within human nervous system, respiratory system and digestive system by making the person an easy prey to various neurological diseases.

- It is of utmost importance to control the acid rain. Short-term control of acid deposition (soil) can be achieved by using lime (Ahluwalia and Sunita, 2008).

## 2.3 SOURCES OF SOME METALLIC POLLUTANTS AND THEIR EFFECTS.

**Table 2.3:** Major sources of metallic pollutant and its harmful effects.

| No. | Metallic pollutant | Major sources | Harmful effects |
|-----|--------------------|---------------|-----------------|
| 1. | Zinc (Zn) | Zinc refineries, galvanizing process, brass manufacture, metal plating, and plumbing. | Zinc fumes have corrosive effect on skin and can cause irritation and damage mucous membranes. |
| 2. | Chromium (Cr) | Metallurgical and chemical industries, process using chromate compounds, cement and asbestos units. | Toxic to body tissues, can cause irritation, dermatitis, ulceration of skin, perforation of nasal septum. Carcinogenic action suspected. |
| 3. | Arsenic (As) | Arsenic containing fungicides, pesticides and herbicides, metal smelters, by product of mining activities, chemical waste. | Inhalation, ingestion or absorption through skin can cause mild bronchitis, nasal irritation or dermatitis. Carcinogenic activity is also suspected. Attack $-SH$ groups of enzymes, coagulate proteins. |
| 4. | Beryllium (Be) | Coal, nuclear power and space in industries, production of fluorescent lamps, motor fuels and other industrial use. | Damage to skin and mucous membranes, pulmonary damage, perhaps carcinogenic. |
| 5. | Boron (B) | Boron producing units, production and use of petroleum fuel and additives, burning coal and industries wastes, detergent formulation. | Ingestion, inhalation as dust causes irritation and inflammation. Boron hydrides can damage CNS and may result in death. |
| 6. | Manganese (Mn) | Ferromanganese production, organo-manganese fuel additives, welding rods, incineration of manganese containing | Absorption, ingestion, inhalation, or skin contact may cause manganic pneumonia. |