Toseef Sethi Candidate number: **7193**

CHEMISTRY OPEN BOOK PAPER

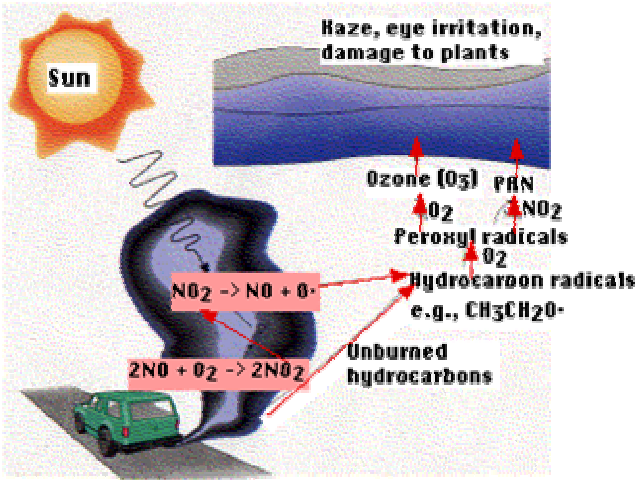
In general, smog is known to be a mixture of smoke and fog, hence the name. Primary pollutants are those emitted directly into the atmosphere[1]. The main primary pollutants formed as a result of motor vehicles are:

> Nitrogen oxides (NO and NO_2)
> Unburnt Hydrocarbons (HCs) due to the incomplete combustion of fuels which are known as volatile organic compounds or VOCs.
> Carbon Monoxide (CO) which is also due to the incomplete combustion of fuels.

With the aid of the sunlight, the primary pollutants mentioned earlier react to form these secondary pollutants:

> O_3 or Ozone
> Nitrogen Dioxide (NO_2)
> Hydrogen Peroxide (H_2O_2)
> Peroxyacetyl Nitrate (PAN)
> Partially oxidised VOCs
> HNO_3

[2]



[3]

The primary pollutants which make up SPM (Suspended particulate matter) are formed by the combustion of fuels in coal-fired power stations. There are three main inputs: cooling water to condense steam from the boilers and very pure water for use in the steam turbines. When the coal burns, the sulphur compounds which it contains due to its composition are converted to Oxides of Sulphur (SO_X) and then released into the atmosphere. The other primary pollutant which is a waste product in this process is Oxides of Nitrogen (NO_X). Fuels burnt in a power station often contain compounds of Nitrogen which are oxidised to form NO_X in the same way as Sulphur[3]. Other than this method of production, thermal NO_X can also be produced. This is when atmospheric Nitrogen and Oxygen react at high temperatures to form NO_X.

In general, the most favourable conditions for forming photochemical smog are bright sunshine and still air. We know that this type of smog forms during high pressure conditions in the lower troposphere which is the part of the atmosphere closest to the ground. This is causes the air to be still and mix with higher altitudes less which means that the primary pollutants are trapped near the ground and maybe even be taken to more rural regions when there is light prevailing wind. The troposphere itself acts as a huge reaction vessel for a number of different chemical reactions. Some of these reactions are photochemical reactions, in which molecules absorb energy from sunlight (often regarded as hv). Most Ozone is created in the troposphere via the following reaction:

$O_2 + O \longrightarrow O_3$ Oxygen molecules and Oxygen atoms react to form Ozone

For this reaction to take place there must be Oxygen atoms available, which are formed by the action of sunlight on NO_2 molecules as in the following equation:

$NO_2 \xrightarrow{hv} NO + O$ Nitrogen Dioxide react with sunlight which must be less than 435nm to make Nitrogen Oxide and Oxygen atoms

This equation therefore shows us the importance of having sunlight and the effects of more sunlight in summer or spring. However, the Ozone is also removed by NO in a reaction which gives Oxygen molecules and Nitrogen Dioxide:

$O_3 + NO \longrightarrow O_2 + NO_2$

In general, the more NO_2 there is available to form oxygen atoms, the more Ozone will be formed.

Hydrocarbons in the atmosphere also play a big part in the concentration of Ozone. Taking Methane as an example, it is first broken down by an OH radical:

$CH_3 + OH \longrightarrow CH_2 + H_2O$

The CH_2 then reacts with an Oxygen molecule to form a Peroxy radical:

$CH_2 + O_2 \longrightarrow CH_2O_2$

The following reaction is the main reason for high concentrations of tropospheric Ozone because it converts NO back to NO_2:

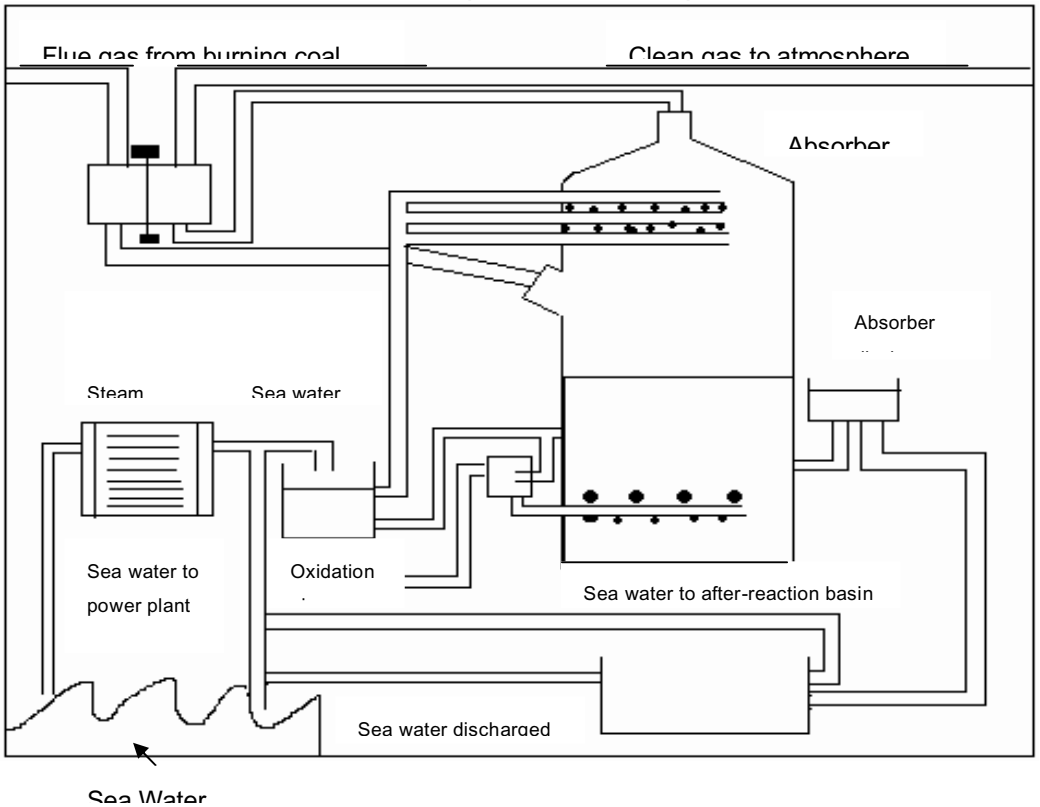
$CH_2O_2 + NO \longrightarrow CH_2O + NO_2$ a never-ending cycle is apparent

The conversion of NO_2 from this reaction is the main source of Oxygen atoms to make Ozone in the first reaction, which is why it is the main reason for tropospheric Ozone. As a result of this cycle there is a constant regeneration of NO_2 which means the concentration of Ozone can only rise. Other than this, the whole process of smog formation described above actually doubles the concentration of O_3 as the following equation shows:

One Ozone molecule $\xrightarrow{\text{Photochemical smog formation}}$ At least two Ozone molecules

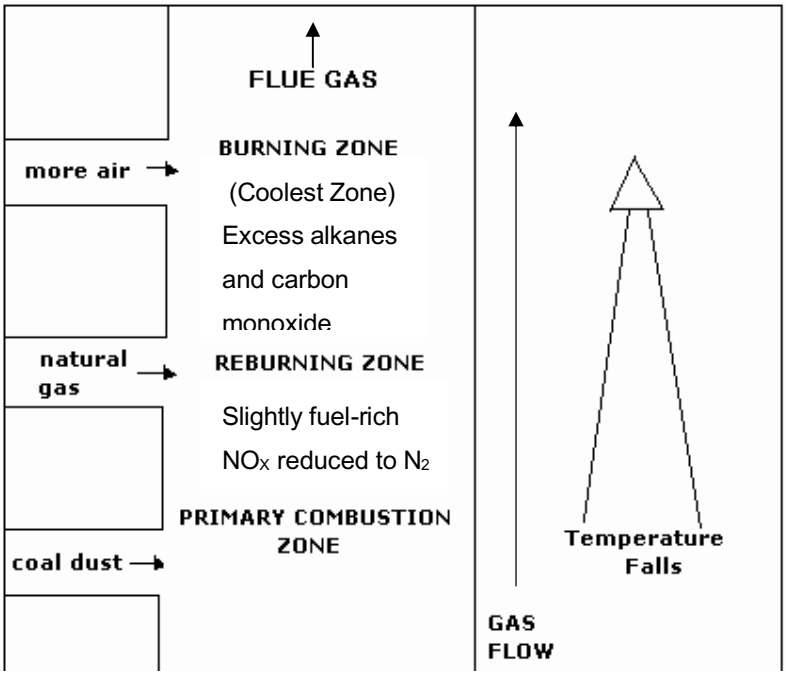
The Longannet power station chose to use the **Sea Water Scrubbing** process as their BPEO (best practical environmental option) for controlling SO_X emissions. In this process, flue gases from the process of burning Sulphur compounds are passed through sea water which is slightly alkaline with a pH of 7.5. The SO_2 in the flue gases then dissolves into the alkaline sea water solution to form Sulphite ions (SO_3^{2-}). These Sulphite ions are still not

as harmless as Sulphate (SO_4^{2-}) ions when disposed of at sea so the water is therefore aerated to oxidise the Sulphite ions to Sulphate ions.



This diagram basically shows the process of sea water scrubbing and what happens to the flue gases in the process.
Interms of minimising NO_X emissions, Longannet power station's BPEO is **gas reburn**. A boiler with three burning zones is used.

At first, in the primary combustion zone, powdered coal is oxidised in less air than normal. Because of this the combustion rate is lowered and less NO_X is formed in a given time.



In the next stage of the process, the NO_X reacts with alkanes (methane and ethane) from the natural gas injected in the reburning zone. This produces CO_2, N and H_2O. Any remaining HCs or CO are oxidised in the burning zone. The reason why Longannet may have chosen the sea water scrubbing to control Sulphur Dioxide emissions is because there are no solid wastes to be placed in landfill and there are no by-products to be handles or marketed. Other than this, they have very quick access to sea water, which is one of the main raw materials they need.
They most probably chose to use gas reburn because some of the heat produced contributes to the electricity made and there are again, no by - products other than harmless gases which are easy to dispose of.

Chemists have a played a big part in research on photochemical smog formation. They have been able to study variations of the concentrations of Ozone and oxides of nitrogen on a summer day in various parts of different cities. They have also tested individual theories in laboratories themselves using different chemicals. Other than this they have been able to simulate photochemical episodes under controlled conditions using smog chambers.

BIBLIOGRAPHY

[1] Environmental Science fact Sheet – www.curriculumpress.co.uk

[2] Website: http://royal.okanagan.bc.ca/mpidwirn/atmosphereandclimate/smog.html#a

[3] Website:http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/A/AirPollution.html