CHAPTER 2

LITERATURE REVIEW

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2.1. Fossil Fuels

The term *fossil fuels* encompass a spectrum of mineral organic compounds extracted from the Earth. They range from solids to liquids and gases, and they include coal, petroleum, shale oil, tar sands and natural gas. Each of these generic names describes a group of materials, often with widely differing properties.

With appropriate chemical processing, fossil fuels can all be converted into similar end products. The common thread is that they all contain hydrogen and carbon and can be called hydrocarbons. Environmental damage is caused by all categories of fossil fuels, to varying extent, although the effects are similar.

Fossil fuels are found in variety of geological formations ranging from surface deposits of coal, oil shale and tar sands to oil pools kilometres below the surfaces of oceans. One of the major activities in the fuel industry is the extraction of fuels from their geological settings.

Major environmental risk in the drilling explorations and production of oil and gas wells will be the possibility of a blow-out which could lead to oil pollution and fire. Even during normal operations, a certain amount of oil leakage occurs although, on a worldwide basis, this has been estimated to be less than 0.02 per cent of the oil extracted off-shore *(Williams, 1994)*.

The impacts of gas exploration and extraction are largely similar to those for oil. Natural gas, however, generally contains less unwanted impurities than coal or oil since the proportions of methane, butane, propane or other energy-rich hydrocarbons are usually quite high.

Burning of fuel oil or refinery gas could also lead to atmospheric pollution. Most oil is burnt in air and the range of combustion products is similar to coal i.e. sulphur dioxide, nitrogen oxides, carbon monoxide and heavy metals. Oil generally has a negligible ash content.

This, combined with generally good combustion conditions, meaning that pollution of particulate matters from the combustion of oil is typically less serious as compared to coal combustion. However, the heavier oil products, such as fuel oil, have high sulphur contents typically in the range of 1 - 3 per cent and produce similar amounts of sulphur dioxide per unit of energy as coal.

Like coal and oil, energy is extracted from natural gas by combustion in air. Clean gas can be almost completely oxidised to carbon dioxide and water, with the percentages of carbon monoxide and soot being low. Thermal nitrogen oxides is formed during combustion but its level of formation can be controlled more easily than for coal.

2.2. Air Pollution by Fossil Fuels

If the Earth is to remain inhabitable, the long range effects of pollution on the atmosphere which blankets the planet can never be neglected. The condition of Earth's environment is very important for man and all flora and fauna. We may be able to avoid polluted water or contaminated food, and we can do a great deal to control or contain radiation, but breathing is not controlled voluntarily and we must breath to live.

Man uses the atmosphere as both a resource and a place for depositing waste. He has expected nature to cleanse out his wastes. But we now recognise that nature cannot do this - not entirely. The natural cycles have their own peculiar rates of, and capacities for, action. Today, wastes are emitted into the air at such enormous rates that the natural process of scavenging cannot keep pace. We have all experienced the result: *air pollution*.

The term *air pollution* has many possible definitions. In general, it refers to an undesirable modification of the atmospheric constituent that may harmfully affect flora, fauna or materials. Thus, to a certain extent whether or not something is an air pollutant is relative to the specific consideration and is arbitrary. The acceptable interpretations will thus evolve with time as influenced by societies demands and by scientific understanding.

We are exposed to more and more pollutants in the ambient air. Common sense indicates that the severity or frequency of adverse effects would also increase. To avoid adverse effects, a balance must therefore be maintained between the amount of contaminants we put into the air and the volume of air available for diluting the substance to a safe level. In this context, anthropogenic pollutants are of more immediate concern because of the possibility and hope that they can be controlled and even eliminated.

Combustion process accounts for a greater volume of air pollutants than any other single source. This is due in part to the inherent nature of combustion and in part to its ubiquitous position in human life. It enters into transportation, heating, cooking, power generation, waste disposal and various industries. Some of these processes are very efficient, converting most of a hydrocarbon fuel into carbon dioxide and water. These two substances are natural components of the atmosphere and are non-toxic.

In most other combustion processes, most chemical reactions fail to go to completion. As a result, a multitude of organic compounds are dumped into the air through the system exhaust when hydrocarbons are burned. In addition, the high temperature of the combustion process causes the nitrogen and oxygen in the air to react to produce nitrogen oxides. The impurities in the fuels also react to form oxides, sulphur oxide being the primary hazardous product.

Combustion of sulphur bearing fuels in power plants under proper reaction conditions forms sulphur oxides in the ratio of 40 to 80 parts sulphur dioxide (SO_2) to one part of sulphur trioxide (SO_3). Sulphur dioxide is highly soluble in water and reacts with water vapour in the air to form sulphurous acid (H_2SO_3). Sulphurous acid subsequently is oxidised to form sulphuric acid (H_2SO_4) *(NIPCC, 1971)*.

In short, the sulphur dioxide and nitrogen oxides produced by combustion of hydrocarbons react with the oxygen and water in the air to produce sulphuric and nitric acids. These acids make rain acid. Acid rain falls on plants causing direct damage. When it falls on ground with a low ability to neutralise acid, it runs into streams and lakes killing plants and animals.

The acid rain that flows over and through soil dissolves metals such as aluminium and zinc and these dissolved metals add to the toxic effects of the acid rain drainage. Total toxic effect of acid rain is strongly dependent on the nature of the soil on which it falls. Concerns about acidification damage were raised in Sweden more than thirty years ago, when the declining fish population in rivers and lakes appeared to be connected to changes in acidity of the water *(Goldemberg, 1996)*.

Although the chemistry of the process is only partly understood at present, it appears that a variety of mechanisms can cause acids to form and that the dominant chemical reactions depend on the location and weather condition as well as on the composition of the local atmosphere.

Acid rain is a persistent problem because we continue to manufacture sulphur and nitrogen oxides in massive amounts by the combustion of hydrocarbons. If we stop the combustion of hydrocarbons, acid rain would disappear in a matter of months *(Williams, 1994)*.

On the other hand, carbon in the hydrocarbon is oxidised into carbon dioxide during the combustion process. The exact rate of this carbon dioxide is not known. Some is adsorbed by the oceans while some will be used by plant life for growth. Much of it remains permanently in the atmosphere. This has resulted in its effect on the thermal balance of the Earth.

The Earth has an average temperature of 20 degree Celsius. It emits most of its energy in the infrared portion of the spectrum at a wavelength of about 10 micrometers. Carbon dioxide is opaque at this wavelength and its presence in the atmosphere reduces the amount of heat the Earth can eliminate. High carbon dioxide concentrations in the atmosphere leave the solar input of energy unaffected, but reduces the amount of energy the Earth can eliminate.

This will increase the average temperature of the Earth and the world weather system will thus change, seeking for a new balance with more energy retained on the surface. As the atmosphere warms, feedback (changes in water vapour, sea clouds and the oceans) amplifies or reduces the warming leading to climate changes.

One of the scenarios would be the melting of ice in the polar regions and the rising of sea level. A sea level increase of only 1 meter will cause severe problems for coastal areas. If we continue to pump carbon dioxide into the atmosphere and the thermal models projecting large temperature increases are correct, a 1 or 2 meter rise can occur within the next 20 years *(Williams, 1994)*.

2.3. Environmental Impacts of Sulphur Oxides

Energy use and environmental degradation are often inextricably linked. As mentioned previously, concern for the environment has increased in importance. Most forms of environmental degradation exhibit their most severe impact near to the pollution sources. Other effects are more disparate.

Polluted air migrates inexorably across national frontiers, with sulphur oxides emissions from one country falling as acid rain in another. The effects of acid rain vary considerably with vegetation, soil types, and weather conditions in a given area. Under some circumstances, the addition of sulphate and nitrate to the soil helps replace lost nutrients, and aids plant growth.

In other instances, however, acid deposition can cause lakes and streams to become acidic, damage trees and other plants, damage man-made structures, and help to mobilise toxic compounds naturally present in soil and rocks. With pH values in lakes well below 5.0, mass extinction of fish populations is occurring due to toxic metals from the lake bottoms becoming soluble in water (and so poisoning the fish) *(Probert et. al., 1989)*.

For instance, Europe's commercial forests suffer damaging levels of sulphur deposition. In Sweden, about 20,000 of the country's 90,000 lakes are acidified to some significant degrees; in Canada, 48,000 are acidic. Sources of the problems in these instances are not solely national *(Mackay et. al., 1995).*

The effects of wet deposition are particularly evident in Norway, where lakes have become acidified and forests damaged. A Norwegian study has also indicated a risk to human health. An increased mortality rate from Alzheimer's disease has been found in southern Norway. This could be due to aluminium, mobilised by acid rain, leaching out into the drinking water supplies *(Probert et. al., 1989).*

On the other hand, relation between the emissions of sulphur oxides at particular sources and acid deposition at distant receptors has also become the subject of several investigations. One of which would be the study carried out by Oppenheimer *et. al.* (1985) in comparing the variations of sulphur dioxide emissions from nonferrous metal smelters in the western United States with the variation of sulphate concentrations in the precipitation in the Rocky Mountain states over a 4-year period. The linear relation between the emissions and sulphate concentration noted in the study despite the geographic separation of emissions sources and precipitation monitors, indicated a sulphur transportation scale of exceeding 1000 kilometers.

2.4. Studies on the Emissions of Sulphur Oxides

Sulphur in its various forms has been identified as a major component of air pollution. There are also a number of significant natural sources of sulphur that were producing sulphur long before civilised man learned to unlock the element from its resting place in beds of fossil fuels.

Studies on the emission of SO_x have been initiated to put the man-made contribution of sulphur compounds to the atmosphere (and oceans) into perspective by comparing it with the contribution of the natural resources. We can no longer study the sulphur cycle in its natural state, since man has already become so active in modifying it *(Kellogg et. al., 1972)*.

Information concerning the concentrations of sulphur compounds in relatively clean air over remote parts of the continents and oceans is quite limited. Many of the early measurements of SO_2 concentrations had been reviewed by Junge in 1963 *(Kellogg et. al., 1972)*. It was also reported that the worldwide concentrations at ground level was 0 - 20 $\mu g/m^3$. However, many of these measurements were made over Europe where the air was already quite contaminated.

As for the estimation of man-made SO_2 emission, perhaps the earliest was that of Katz in 1959 who made estimates for each year during the period from 1937 through 1947 *(Kellogg et. al., 1972)*. He estimated that in 1943, the total amount of sulphur emitted, calculated as SO_2, was 77 x 10^6 metric tons and about 67 per cent of these emissions were resulted from the burning of coal.

In the mid-1960's, Robinson and Robbins estimated an annual emission of 146 x 10^6 tons where about 70 per cent was resulted from coal burning and another 16 per cent from the combustion of petroleum products *(Kellogg et. al., 1972*).

As for the U.S., the most exhaustive review in the earlier days is contained in the report of the Study of Critical Environmental Problems (SCEP) *(Kellogg et. al., 1972)*. The report which adopted a different set of emission factors, based on the statistics in the United States for 1967 and 1968, concluded that worldwide production of SO_2 from the burning of fossil fuels amounted to 66 x 10^6 tons.

It was highlighted that, although this is a worldwide figure, it is significant that about 93.5 per cent was produced in the Northern Hemisphere, and only 6.5 per cent in the Southern Hemisphere.

2.5. The Scenario in Asia

Although, until recently, acidification of the environment has been regarded as a problem only in Europe and North America, the problem has also started to emerge in parts of Asia. The countries of Northeast Asia has already begun to experience some important impacts of acid rain. Forest health in some areas of the Koreas, China, and Japan has already revealed evidence of degradation that points to acid rain *(Von Hippel, 1996).*

Hamburger (1995) reported that man-made materials such as zinc-plated steel have drastically shorter-than-normal life times in south China, and irreplaceable cultural landmarks made of limestone and other substances are being degraded at an accelerating rate *(Von Hippel, 1996).* While some industrial sources of emissions, particularly the smelting of metal, can be important sources of sulphur oxides, the energy sector accounts for a large fraction of these emissions.

Asia is experiencing rapid economic and population growth. It is estimated that by the year 2010 over 4 billion people will be living in eastern Asia and the Indian sub-continent. Additionally, these countries are experiencing phenomenal economic expansion; for example, China has experienced 9.5% GDP growth between 1980 and 1990 *(Carmichael et. al., 1996).*

This rapid growth in the many Asia economies has resulted in significant growth in the region's energy needs *(Akimoto et. al., 1994)*. As reported in the *Global Environment Outlook (GEO-2000)* by the United Nations Environment Programmes (UNEP), demand for primary energy in Asia is expected to double in every 12 years while the world average is every 28 years.

This growth has not come without environmental consequences. Environmental pollution issues also appear more seriously as the emission of pollutants from fossil fuel combustion increases *(Furuse et. al., 2000)*, with growth in sulphur oxide emissions paralleling the region's expanding energy needs *(Foell et. al., 1995)*.

The impact of Asia's deteriorating air quality could have wide-ranging consequences for the region. Many urban centres in Northeast Asia have air pollution levels exceeding the World Health Organisation's (WHO) ambient standards *(Mage et. al., 1996)*. Acidic precipitation is being reported throughout the region, with many areas already receiving levels which exceed the acidic carrying capacity of their soils *(Carmichael et. al., 1996)*.

Although acid deposition can be a local phenomenon, particularly in urban areas and in areas near to a large point source of emissions, the extent to which acid gases are carried by prevailing weather patterns makes acid rain a truly regional issue, one that frequently crosses national boundaries *(Von Hippel, 1996)*.

The transport and fate of sulphur in Asia is an area of increasing environmental interest and concern as countries receive growing amounts of sulphur from neighbouring and even distant countries *(Arndt et. al., 1996)*. A recent analysis of sulphur deposition in Japan by Fujita (1996) which utilised present measurements and estimates of sulphur emissions, concluded that Japan receives more sulphur deposition than can be attributed to its own emissions *(Carmichael et. al., 1996)*.

As Jefferson (1997) has rightly pointed out in his survey on behalf of the World Energy Council to the nine Regional Groups, pertaining to the energy and the enviornment for the scenarios to 2100, local issues were accorded of significantly higher priority than the issue of possible climate change.

2.6. Emissions of Sulphur Oxides in Asia

As majority of the growth of emissions in the next two decades will likely be in China, a substantial regional, if not international, cooperative effort will be required to reduce emissions before the level of environmental damage become overwhelming. How and where sulphur will be deposited is an area of increasing environmental concern.

In order to better understand how future emissions may affect acidification in Asia, it is necessary to develop relationships between sources of sulphur and their resulting deposition patterns as high sulphur deposition regions follow closely the spatial distribution and density of emissions. Despite the needs, Asia has never had a good investigation of its energy consumption *(Kato, 1996).*

Reliable estimation of anthropogenic emissions of acid rain precursors is important in order to understand their geographical origins. Furthermore, assessment of region-specific emissions by economic sector and fuel type is necessary in order to be able to formulate effective strategies for the mitigation of these precursors *(Shrestha et. al., 1996).*

The total amount of SO_x emitted from Asia amounted to 29.1 million tons in 1987 from 18.3 million tons in 1975 with the average annual growth rate of 3.9% *(Kato, 1996)*. The calculation was done by 27 kinds of fuels and in 17 sectors. In another study by Shrestha *et. al.* (1996), the total emissions of SO_2 in the region were estimated to be about 38 million tons in 1990, almost 56% higher than that of North America.

Both studies had identified China, Japan and South Korea among countries that contributed the largest share of sulphur oxides emissions in the region. Triendl (1998) also reported that total sulphur emissions from 20 Asian countries have been estimated at 34 million tonnes in 1990, with north Asian countries accounting for more than three-quarters. Of them, China was the largest emitter and had increased her share further in the total of Asia remarkably from 56% in 1975 to 69% in 1987, and, on the contrary, Japan, South Korea and Taiwan had decreased their shares *(Kato, 1996)*.

Countries in the North-East Asia (China, Hong Kong, Japan, South Korea, Mongolia and Taiwan) contributed almost 78% of the total emissions of SO_x in Asia, followed by the South Asia (15%) and South-East Asia region (7%). Shrestha *et. al.* (1996) correlates this with the type of fuels consumed by these countries and concluded that the emissions were found to be relatively high in most of the coal-dominated countries.

He added that low SO_2 emission (below 30 thousand tons in 1990) from Bhutan, Cambodia, Laos, Myanmar and Nepal can be attributed mainly to the predominance of traditional (biomass) fuels, the sulphur contents of which are much lower than that of fossil fuels.

Nevertheless, according to the calculations by the World Bank before the 1997's financial crisis, emissions from the Asia region could rise to 78 million tonnes by 2010 if no firm action is taken. In Europe, on the other hand, sulphur emissions are expected to decrease from 38 million to 14 million tonnes over this period as a result of stringent controls *(Triendl, 1998)*.

It was also noted that most Asian countries' energy intensities are higher than those in the industrialised countries *(Shrestha et. al., 1996)*. These higher values of energy intensities in most Asian countries had partly reflected the low efficiency of energy use in most of the countries.

2.7. Emission Sources of Sulphur Oxides in Asia

Efficiency of electricity generation from coal-fired power plants was reported by Shrestha *et. al.* (1996) to be significantly lower in China (31.3%) and India (28.4%), as compared to the 38.8% in Japan and 36.9% in OECD countries. This partly reflects relatively high levels of pollution from the energy intensive production sectors and the lack of emission controls in Asia.

Kato (1996) reported that the share of industrial sector, which contributed the largest share in the total emission in Asia, had decreased from 43% to 38% from 1975 to 1987, and the share of the emission from the energy transformation sector had increased considerably (25% to 29%) for the same period. The sector also presented an average annual growth rate of 5.4% which exceeded the other total sectors combined (industry, transport, refineries etc.).

At individual country level, power generation had the largest share of national emissions in India, Hong Kong, Malaysia, Philippines, Thailand, Singapore, Brunei and Mongolia *(Shrestha et. al., 1996)*. While this might incline that the present level of air quality in the South East Asian countries is still within tolerable limits, continuous industrialisation and rapid urbanisation compounded with the rapid increase in population will turn the tide and eventually lead to the destruction of environment unless air pollution abatement measures are taken up.

In lights of the present heightened awareness and concern for the environment, experiences in the past have brought each and every individual a realisation that a more proactive participation and commitment in environmental management concerns are imperative.

The complex land-sea configuration of the ASEAN region create scales of atmospheric motions as well as its interaction with the monsoon and global scale motions which, give rise to diverse localised climatic regimes in the region, rendering it as a potential for transboundary air pollution as evidenced by the worst haze episodes in 1994 and 1997 *(Merino, 2001).*

On the other hand, acidification of the environment resulting from emissions which was once a problem in Europe and North America has been reported to have occurred in some parts of Asia. The most sensitive areas are in South China, the southeast of Thailand, Cambodia and south Vietnam *(UNEP, GEO-2000).*

In a study which compare critical loads with the estimates of sulphur deposition to identify which ecosystems may be at risk under various emission scenarios, vast regions of Asia are predicted to be in excess of critical load. These areas include vast regions of east and south China, South Korea, southern Japan, Taiwan, and areas in India, Bangladesh, Thailand, Malaysia and Indonesia (Carmichael *et. al.*, 1996).

The study had also concluded that the growth of sulphur deposition could have a severe negative influence on the conditions of many important agricultural crops, including rice growing, in Asia.

Although the current state of scientific knowledge does not yet allow drawing conclusions about the environmental damage implied with such excess deposition, the fact that sulphur deposition will be more than ten times above the sustainable levels in large areas may give reason for serious concern *(Carmichael et. al., 1996)*.

There is clearly a great need to conduct more model comparisons and fundamental studies to better determine the most suitable parameters for use in modeling studies in the region. In this regard, concern about the problem of acid rain in East Asia had led nine countries, including Japan, South Korea, Indonesia, Thailand, Malaysia and Russia, to discuss setting up a regional monitoring network *(Triendl, 1998)*.