Yuechuan Yu

Air Pollution: History and Some Methods for Control

Abstract

Air pollution is a major threat to human health and the environment. Modern equipment, such as the catalytic converter and the flue exhaust scrubber are useful for reducing toxic smog and acid rain. Developing countries suffer from pollution problems due to rapid modernization, insufficient regulation and reluctance to pay for upgraded industrial and domestic equipment that can reduce emission of pollutants. Economic development, stricter regulation and moving to less-polluting equipment will ameliorate global pollution.

Introduction

Air pollution is a physical (i.e. dust particles), chemical or biological contamination of the atmosphere. Due to modern technology (automobiles) and industry (coal-fired power generators), air quality has rapidly decreased, creating health hazards, damaging the environment and atmosphere (ozone), creating meteorological problems (global warming), decreasing agricultural output and defacing the land (or city) -scape.

According to the World Health Organization (WHO), air pollution is directly responsible for 4.6 million deaths each year since the mid-1990's. In 1952, coal and automobile smog resulted in 12,000 deaths in London over two months.

In early 2007, an international commission of renowned scientists has attributed the problem of global warming to industrial and vehicle air pollution (carbon dioxide from combustion of fuels). The destruction of ozone by Chlorofluorocarbon (CFC) pollution from aerosols and air conditioners is a concern because ozone protects against carcinogenic UV radiation. Air pollution has become possibly the most significant danger to mankind's survival. Better technology (i.e. catalytic converter) and strict regulation (CFC ban) have contributed to decreasing the rate of air pollution. (Wikipedia: Air Pollution; History of Air Pollution)

Prior to about 1750, air pollution was often due to wood burning during winter months in large urban centers, such as Rome. Air pollution increased in the late 1600's

due to burning of coal. By the early 1800's, the pace of the Industrial Revolution demanded massive amounts of coal for factories and locomotive engines. Residents of major industrial centers, such as Sheffield, England and Essen, Germany often suffered respiratory ailments. The major industrial cities were sources of fumes, smog and soot.

By the late 19th and early 20th Centuries, air pollution was so prevalent in developed countries that its reduction became a national priority after a series of catastrophes. In 1892, over 1,000 London residents died from smog. In 1963, the U.S. government implemented the Federal Clean Air Act to enact environment laws based on scientific data. Between 1960 and the present, various measures to control air pollution were enacted based on growing information on environmental damage, such as ozone depletion, acid rain and global warming and health effects, such as cancer and respiratory ailments. Despite these measures, air pollution remains a great threat due to population increase, growing automobile and energy use in Western countries and in developing countries, such as China and India.

In Western countries (and to a lesser extent in developing countries), several technical advancements have been implemented to reduce air pollution. The catalytic converter for vehicles reduces smog-forming nitrogen oxides to elemental nitrogen and oxygen. The electrostatic precipitator reduces emission of particles from electric power plants that burn coal or oil. Desulfurization processes remove sulfur dioxide from power-plant flue gases. As of 2007, only national regulatory measures can reduce carbon dioxide emissions due to the lack of an effective scientific solution.

Processes

The Catalytic Converter (Figure 1)

A major source of nitrogen oxides is the automobile due to fuel combustion. Nitrogen oxides (NOx) contribute to acid rain in the form of nitric acid. Acid rain affects agriculture by increasing soil acidity and leeching away nutrients as well as physical damage to vegetation. Forests and marine life suffer heavily from industrial and automobile acid rain. City smog (brown fog) consists of nitrogen oxides primarily from automobiles. These are irritants that can cause eye and lung damages.

As shown in **Figure 1**, a three-way catalytic converter converts nitrogen oxides to elemental nitrogen and oxygen, converts poisonous carbon monoxide to carbon dioxide and converts unburned hydrocarbons to water and carbon dioxide. Inside the converter, there are two main sections, one for reducing nitrogen oxides and the other for oxidizing unburned hydrocarbons and carbon monoxide. Each section contains a ceramic "honeycomb" structure covered with a metal catalyst for reduction or oxidation purposes. The honeycomb structure is highly porous to provide a large surface area for catalysis. The catalyst for reduction is rhodium or platinum metal and that for oxidation is a platinum and palladium alloy. The rate of catalysis is rarely perfect because the rate of catalysis is sufficient only at higher temperatures. Usually, cars starting up in cold conditions tend to expel uncatalyzed gases. Because the catalytic converter does not reduce carbon dioxide emissions, it does not contribute to alleviating global warming.

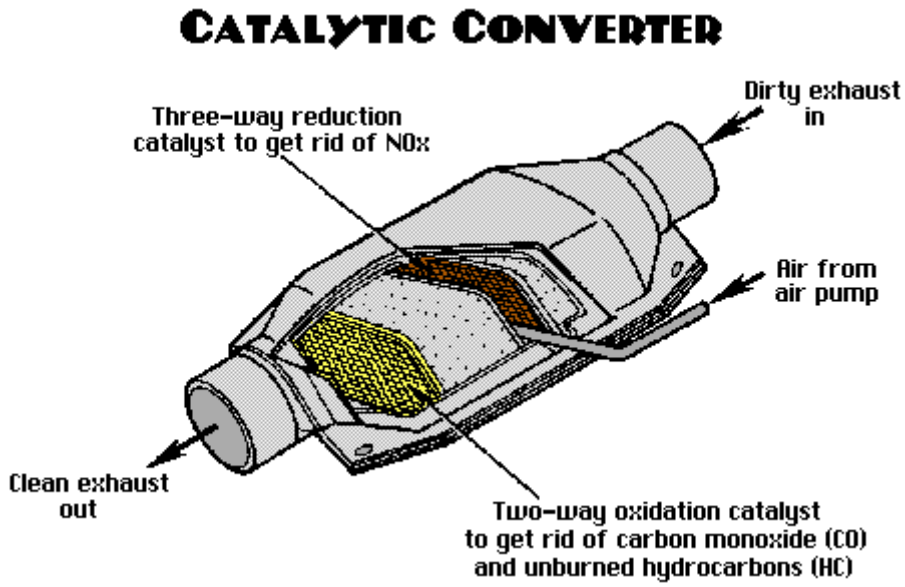

Figure 1: A catalytic converter.

Electrostatic Precipitation (Figure 2)

Fuel-burning factories expel large amounts of 'flyash,' a smog of noxious fumes and soot that contribute to city smog and acid rain. The fumes must not contain unburned hydrocarbons (which may combust and damage the precipitator). **Figure 2** shows a schematic of an electrostatic precipitator. First, the exhaust is vented past negatively

charged plates, giving the particles a negative charge. Afterwards, a second, positively charged plate attracts and collects the particles. Electrostatic precipitators are highly efficient, collecting up to 90% of particles in a factory exhaust.

A variation to this method is the wet electrostatic precipitator that circulates water on the surface of the precipitator. Sulfur dioxide and nitrogen oxides are collected because they are soluble in water.

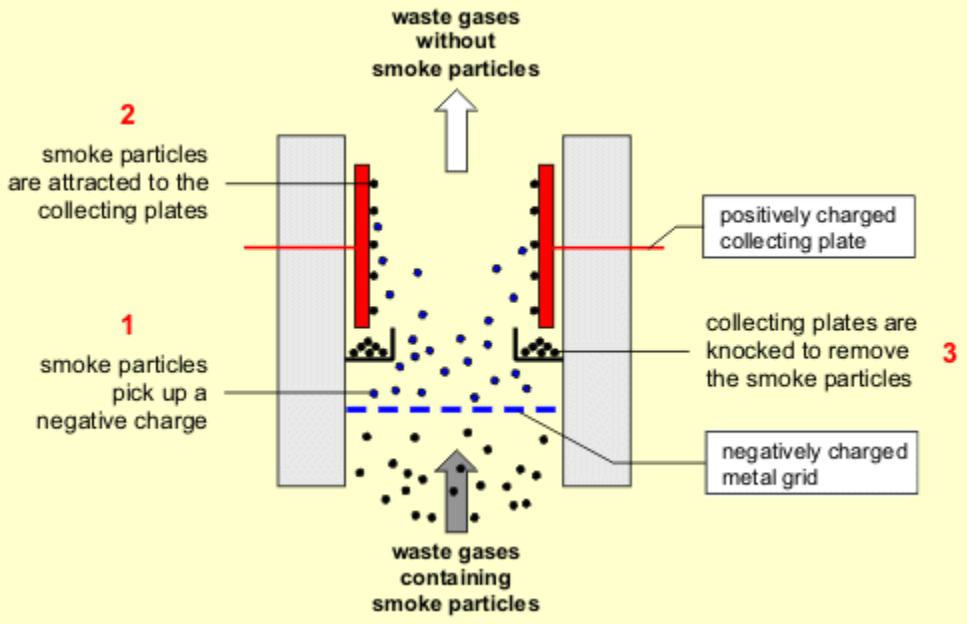

Figure 2: Schematic of an electrostatic precipitator.

Flue Gas Desulfurization

Sulfur dioxide is a major component of acid rain. Following oxidation to sulfur trioxide, sulfuric acid is formed upon contact with moisture. The key to sulfur dioxide removal is conversion to sulfate and subsequent precipitation into a solid. First, the exhaust is collected and then pumped into a collection tank sprayed with a 10% lime solution (essentially CaOH solution) to react with the sulfur dioxide. Calcium sulfites or sulfates are precipitated. The solids are collected and dried before disposal in landfills or as gypsum, a useful mineral for construction and agriculture.

Flue-gas desulfurization is a highly efficient process, using about 1% of an energy plant's output and removing 80-95% of sulfur dioxide.

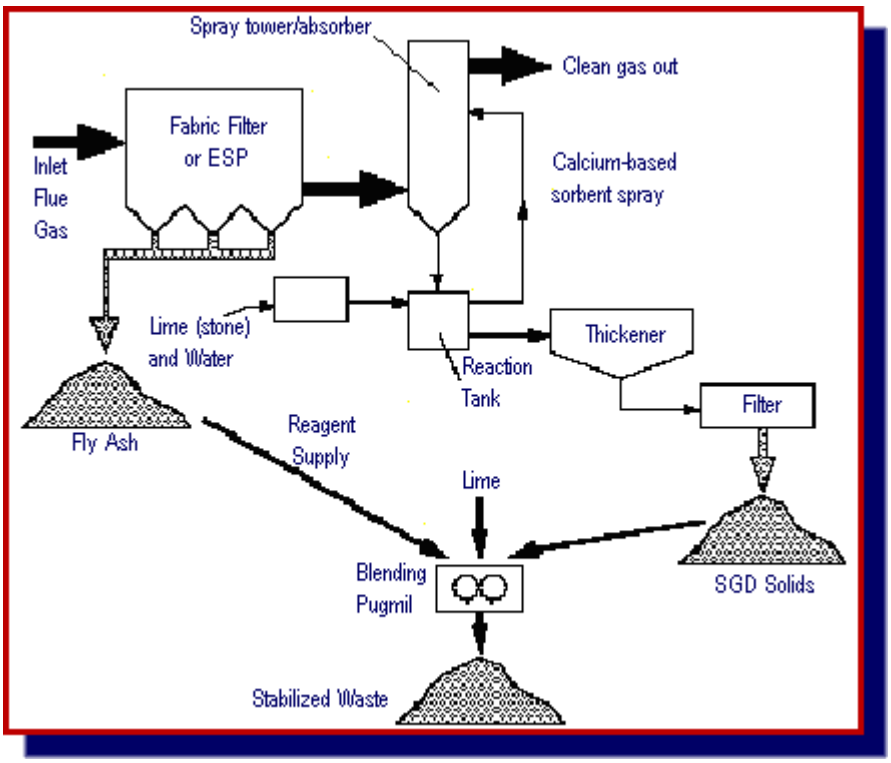

Figure 3: Lime/limestone-based Flue Gas Desulfurization schematic.

Consequences

Before national regulations that require air-pollution treatment methods and control in the 1960's, heavy smog and severe acid rains were constant problems in developed countries. Deaths from smog asphyxiation were common. Notorious examples include the "Great Smog of London" in 1952-53 when over 12,000 people died from December to January due to the effects of concentrated coal and automobile smog. Acid rain was a significant problem in the 1960's and 1970's. The German Black Forest was heavily damaged, where trees were stripped of leaves and bark due to acid rain formed from exhausts in French factories. Forests in the Detroit area were also affected in a similar manner due to emissions from the steel and auto industry.

In developed countries, deaths due to smog ceased due to smog reduction in major cities after the 1970s. Improvement was achieved by removing outdated coal-based power plants, the use of catalytic converters in automobiles and filters in factories. However, automobiles continue to release large amounts of carbon dioxide; however, car emissions are now non-toxic because of low emissions of carbon monoxide and nitrogen oxides. Illness due to smog is a major problem in developing countries that account for

most of the global deaths due to air pollution. In large cities like Mexico City, Tehran, Beijing and New Delhi heavy smog is a major cause of respiratory sickness. Mexico City has levels of nitrogen dioxide two to three times over safe levels. In December 2005, 1600 people in Tehran suffered from respiratory ailments due to smog. Coal-burning factories and old or under-serviced automobiles are very common in these cities. However, increased environmental regulations and affordable pollution-reducing equipment, especially in China and India, are slowly improving the current pollution situation.

Heavy acid rain in Europe and the United States is now rare. However, it is still a problem, especially in China, where forests in the northeast province Heilongjiang are decimated from acid rain due to unprocessed exhausts from steel mills and coal-burning factories. These old, communist-era factories are gradually phased out, replaced by for newer fuel-burning, nuclear or hydropower plants with modern filtering equipment.

Global Efforts for a better Environment

The Kyoto Protocol is the first major international treaty for the control of carbon dioxide and other greenhouse emissions. Despite the greenhouse control measures and limits, the major greenhouse contributors are not bound to the treaty. The United States is currently the largest greenhouse gas contributor and has signed the Kyoto Protocol yet has not ratified it. China and India are the second and third largest greenhouse gas emitters but are exempt because they are classified as developing countries by the protocol and not subject to emission limits. The Kyoto Protocol places greenhouse gas limits on developed countries, mainly on the EU, which contains the most developed countries that have ratified the protocol, and Japan.

Currently, not a single country that has ratified the Kyoto Protocol has enacted national legislation to enforce obligatory measures according to the protocol. When the United States signed the protocol in 1997, the Senate and President Clinton demanded equal measures are placed on both industrialized and developing countries. According to the Congressional Budget Office and Department of Energy, enacting the Kyoto Protocol would have detrimental effects on GDP. Power, automobile and chemical industries, for

example, would be required to use expensive, environmentally-friendly production methods that would significantly decrease profits.

The Kyoto Protocol uses 1990 as the basis year for its measures and the categorization of countries into fully industrialized and developing statuses. Many countries feel this is an inflexible, unequal and illogical basis to determine limits on emissions. The countries are placed according to their emissions as a fraction of the global output in 1990. Some countries, such as China and India, have current emission outputs that, if categorized according to the 1990 regulations, should be considered developed. The United States have called for carbon dioxide limits based on real-time emission values.

Three main principles of the Kyoto Protocol can be summarized to favor developing countries. First, developing countries are not responsible for the majority of the greenhouse gases that is causing global warming. Second, the emissions values per capita of developing countries are low. Third, emissions from developing countries are expected to naturally rise as a part of industrialization. These arguments have been recently put forward by China and India in response to the United States' calls for their emissions curtailment.

The emissions target for developed countries set by the Kyoto Protocol is to reduce emissions by at least 5% from the 1990 values in 2008-2012. However, for certain countries, this would mean reducing emissions 15% lower than their economic targets, causing great financial loss. A new, 'flexible' measure to encourage participation of developed countries is 'emissions trading'. Governments would provide incentives to industries to reduce emissions. The Clean Development Mechanism is another way to help developed countries reach their obligations by allowing them to provide financial and technical aid to developing countries on emission reduction projects.

Most analysts predict that all of the developed countries that have ratified the protocol can meet their obligations, but most of progress will come from Eastern European countries and Russia due to their stark decline in industry after the fall of the Iron Curtain and the Soviet Union.

The Kyoto Protocol was the first attempt at unifying global efforts to reduce carbon dioxide emissions, seen as the main element of global warming. Despite the flaws

and disagreements due to the protocol, the treaty created international awareness of global warming and pollution. New, regional treaties have been made to complement the Kyoto Protocol to attain realistic progress in emissions control. For example, the Asia-Pacific Partnership on Clean Development and Climate was ratified in 2005 by China, India, U.S., Japan, South Korea and Australia to initiate 100 programs aimed to create sustainable clean energy capacity.

Case Study: China

After a decade of economic, cultural and social chaos during the Cultural Revolution from 1966-76, the Chinese leadership headed by Deng Xiaoping embarked on a plan of rapid modernization and economic growth. China was playing catch-up at a feverish pace and nothing was spared for the sake of economic progress. A major side-effect is pollution, a natural byproduct of industrialization, increased due to the pace of progress and affordability.

By 1998, the air in two thirds of Chinese cities was moderately or severely polluted. The 'Asian Brown Cloud' and 'Asian Haze' are global effects linked to Chinese pollution. The former is city and factory smog that have accumulated and absorbed by ocean wind currents, spreading to Japan, Russia and the Pacific. The Asian Haze is a mixture of smog and dust that accumulates during summer and spreads to Korea, Japan and Russia. Land overuse in Northern China is the main reasons for the Asian Haze. Experts predict China will be the greatest source of aerial pollutants and greenhouse gases in the world by 2010.

Japan and the United States are major critics of Chinese air pollution. Chinese pollution has been spreading to Japan and creating acid rain, affecting agriculture and aquaculture, as well as smog in cities. The United States believes that China should take more responsibility as part of a global effort to reduce greenhouse gases as a condition for active participation by the U.S.

The Chinese stance to both countries is primarily indifferent or defensive. China believes that it is targeted by the U.S. as part of a strategy to weaken the nation's economy for fear of new superpower rival in the world. Furthermore, there is a sense of

autonomy because China portrays itself as a reawakening superpower that was suppressed and humiliated for over 150 years by foreign powers.

With Japan, the situation is complicated by history. China believes that Japan has not fully atoned for its wartime (1937-1945) crimes against civilians and prisoners of war. Examples include the Japanese Prime Minister visiting the Yasukuni Shrine, which also memorializes war criminals, and the exclusion of Japanese crimes in history textbooks. Therefore China believes Japan already has a large debt to owe and views Japanese demands with animosity.

Conclusion

Air pollution is one of the most significant problems facing humanity today. Technical advances, such as the catalytic converter, are important for controlling pollution levels. Developing countries currently lag and their citizens suffer from many health problems. Better cooperation between developed and developing countries, stricter regulations and availability of affordable and effective technologies are critical for reducing the global warming issue, toxic city smog and environmental damage.