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IMPACTS OF AIR POLLUTION

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CHAPTER - 1

AIR POLLUTION HEALTH AND ENVIRONMENTAL CONCERNS

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Both natural and artificial causes contribute to air pollution. Anthropogenic air pollution is caused by human-driven activities aimed at delivering vital products and services to society. Air pollution emissions occur throughout the product and service life cycle, from raw material extraction through energy acquisition, production and manufacture, consumption, reuse, and recycling, and finally disposal. The resulting emissions undergo a variety of physical and chemical transformations, contributing to a variety of health and environmental effects such as deterioration of air quality, toxicological stress on human health and ecosystems, photo-oxidant formation (smog), stratospheric ozone (O_3) depletion, climate change, degeneration of air resources, and noise, among others.

Air pollution is a serious environmental health issue, causing an estimated 2 million premature deaths globally each year. Individuals have little control over their exposure to air pollution. demands national, regional, and even worldwide action by government organisations and public authorities. People in underdeveloped nations bear more than half of the impact of air pollution on human health. The average yearly level of PM10 (particulate matter [PM] with an aerodynamic diameter equal to or less than 10 m, the major source of which is the combustion of fossil fuels) in many cities exceeds 70 g/m3. According to the WHO Air Quality Guidelines (AQGs), these values should be less than 20 g/m3 in order to avoid illness. We can assist nations minimise the worldwide burden of illness caused by respiratory infections, heart disease, or lung cancer by lowering air pollution levels.

severe environmental health issue that affects both developed and developing nations. Based on numerous research, the WHO created AQGs to reflect the most universally agreed-upon and up-to-date evaluation of the health consequences of air pollution and to suggest air quality objectives that considerably decrease health risks. The most recent WHO AQGs from 2005 provide updated worldwide guidelines on decreasing the health effects of air pollution. The updated (2005) recommendations (WHO, 2006) apply globally and are based on expert assessment of current scientific data. They propose updated limitations for specific air pollutants, such as PM, O3, dioxide (NO2), and sulphur dioxide (SO2), that are relevant across all WHO areas. The following are the key discoveries of 2005 AQGs.

Even modest levels of air pollution are linked to a variety of negative health impacts. Exposure to PM and O3 poses major health concerns in many cities in both developed and developing nations. Poor indoor air quality (IAQ) may endanger the health of more than half of the world's population.

PM levels in households where biomass fuels and coal are used for cooking and heating may be 10-50 times higher than recommended limits.

Lowering the amounts of some of the most prevalent air pollutants generated during the burning of fossil fuels may significantly reduce exposure to air pollution. Surprisingly, such methods will also lower greenhouse emissions and aid to global warming mitigation.

Of all air contaminants in ambient air, particulate matter (PM) impacts more individuals than any other pollutant. The harmful effects of PM on human health occur at levels of exposure already encountered by the majority of urban and rural residents in both industrialised and developing nations. Sulfates, nitrates, ammonia, sodium chloride, carbon, mineral dust, and water are the primary elements of PM. PM is a complex combination of organic and inorganic solid and liquid particles floating in air. Particles are classified as PM10 (aerodynamic diameters equal to or less than 2.5 m) or PM2.5 (aerodynamic diameters equal to or less than 2.5 m). The latter are thought to be more dangerous because, when breathed, they may reach the peripheral areas of bronchioles and interfere with gas exchange within the lungs.

Persistent particle exposure increases the chance of developing cardiovascular and respiratory disorders, as well as lung cancer. Exposure to pollution from indoor burning of solid fuels on open fires or traditional stoves increases the risk of acute lower respiratory infections and related death among young infants in underdeveloped nations. Indoor air pollution caused by the use of solid fuels is a substantial risk factor for chronic pulmonary fibrosis and lung cancer in adults. Mortality in polluted cities surpasses that seen in comparatively clean ones. Cities will be 15-20% cleaner. Even inside the European Union, the average life expectancy is decreasing. About 8.6 months shorter as a result of PM2.5 exposure caused by human activity. According The PM2.5 guideline limits are determined in accordance with the 2005 WHO AQGs (WHO, 2006). and PM10 on their own. PM2.5 and PM10 yearly means should be equal to 10. and 20 g/m3, respectively, with the 24-hour mean not exceeding 25 and 50 g/m3 in each case. It is worth noting that the 2005 AQGs for the first time contain a suggested value for PM. The goal is to attain the lowest possible concentrations. Considering there is no PM threshold beyond which no harm to health is caused, noted, the proposed value should indicate a reasonable and attainable goal reduce health impacts in the context of local restrictions, capabilities, and resources as well as public health considerations (WHO, 2006).

In the case of O_3, the previously advised limit of 120 g/m3 was maintained. According to recent convincing connections, the 8-hour mean was lowered to 100 g/m3.between daily mortality and O_3 levels at O_3 concentrations less than 120 g/m3 (WHO, 2006). Ground-level O_3 is a significant component in photochemical reactions. smog. It is created by the photochemical interaction of pollutants like nitrogen oxides (NOx) from automobile and industrial emissions and volatile organic compounds with sunlight. VOCs are organic molecules released by cars, solvents, and industries. The greatest O_3 pollution levels are highest during sunny hours. Tropospheric O_3 levels are susceptible to local NOx and VOC concentrations. According to model studies, increased UV-B light lowers tropospheric O_3. pristine settings (low NOx) while increasing tropospheric O_3 in dirty places (high). NOx). Excessive O_3 in the air may have a significant impact on humans.

Health, material, and vegetation are all important considerations. It may cause respiratory issues and precipitate asthma attacks. impair lung function, and induce lung illnesses. It is now one of the airborne threats in Europe. contaminants of greatest concern. According to many European research, the daily Mortality increases by 0.3% and that for heart disease increases by 0.4% for every 10 g/m3 increase in O3 poisoning (WHO, 2006). The primary sources of anthropogenic NO2 emissions are combustion activities. Epidemiology research have seen a rise in bronchitis symptoms among asthmatic children. with long-term exposure to NO_2. NO_2 has also been associated to decreased lung function growth. Concentrations presently recorded (or seen) in European and North American cities. The current WHO recommendation is 40 g/m3. established to safeguard the public (annual mean) the health consequences of gaseous NO2 remain unaltered from the acceptable level AQGs that have come before. A 1-hour mean AQG value of 200 g/m3 is also provided. recommended. NO_2 has numerous linked actions as an air pollutant: It is a hazardous gas that causes cancer at short-term doses greater than 200 g/m3. The airways are inflamed significantly. NO_2 is the primary source of nitrate aerosols, which account for a significant proportion of the total. in the presence of UV light, of small particles, and of O_3. SO_2 is created by the combustion of fossil fuels (coal and oil) and the smelting of metals. Mineral ores containing sulphur.

Sulfur-containing fossil fuels (such as coal) are used for residential heating, electricity generation, and motor vehicles. According to studies, a fraction of persons with asthma suffer changes in pulmonary function and respiratory symptoms after 10 minutes of SO2 exposure. A SO2 concentration of 500 g/m3 should not be surpassed during 10-minute average intervals, and 20 g/m3 should not be exceeded over a 24-hour mean period. The adjustment of the 24-hour SO2 recommendation from 125 to 20 g/m3 is based on the fact that health impacts are now recognised to be connected with far lower levels of SO2 than previously thought, necessitating a higher level of protection. SO2 may harm the respiratory system and lung functions, as well as irritate the eyes. Inflammation in the respiratory tract promotes coughing, mucus output, worsening of asthma and chronic bronchitis, and renders patients more susceptible to respiratory infections. On days with greater SO2 levels, hospital admissions for heart illness and death rise. As SO2 reacts with water, it produces sulfuric acid, which is the major component of acid rain, which harms delicate ecosystems.

It should be noted that the WHO AQGs (e.g., WHO, 2000, 2006) are designed to offer governments with consistent background knowledge and direction when making health risk management choices, especially when creating standards. The recommendations may also be utilised in community or regional planning procedures and many types of air quality management choices. The AQG publication notes that the recommendations are really not standards in and of themselves. The guideline values must be assessed in the context of current exposure levels, technological feasibility, source countermeasures, abatement techniques, and social, economic, and cultural situations before they are transformed into legally enforceable norms. In certain cases, there may be compelling reasons to adopt policies that result in air pollutant concentrations above or below guideline levels. While these recommended limits are thought to preserve human health, they are far from a "go ahead" for pollution. It should be emphasised that efforts must be taken to reduce air pollution levels as low as realistically possible, since there is no definite threshold or level below which no deleterious effects occur [1], [2].

The health burden of environmental exposures, such as ambient air pollution and the health effects of climate change, is not evenly spread between or within regions and nations. These discrepancies are presently garnering increasing attention in climate change research as well as growing recognition in environmental policy, where demands for environmental equality are becoming more common. Even the WHO Global Update of the AQGs (WHO, 2006), which attempts to address global-scale inequalities in exposure to air pollution and the burden of diseases caused by air pollution, falls short of explicitly addressing inequalities in exposure and adverse health effects within countries and urban areas due to the differential distribution of sources of air pollution such as motor vehicles and local industry, as well as differences in susceptibility to the advective effects of air pollution. These disparities, however, may be addressed via local air quality and land use choices.

With this in mind, the current book contains not only basic information and principles of the air pollution issue, but also research and instances from throughout the globe, allowing the unique characteristics of each place to be recorded. It is hoped that the book will help readers (i) better appreciate social and environmental determinants of public health, and (ii) apply country-based research evidences to reduce health disparities and environmental inequalities, in addition to understanding the scientific basis of air pollution and its impact on health and the environment. Moreover, the book is designed to promote future study and policy action on the health and environmental impacts of air pollution at all levels, from local to global.

The chapters cover almost all of the major aspects of air pollution, such as monitoring and source characterization of air pollution, modelling, health effects, environmental impacts, risk assessment, air quality management, and relevant policy issues, to help readers appreciate and comprehend the complex problem of air pollution and its adverse effects on human health and the environment in total. The book is structured into five primary parts to aid comprehension: Air Pollution Monitoring and Modeling, Air Pollution and Health Consequences, Health Risk Assessment and Management, Air Quality Management: Methods and Policy Issues, and Environmental Impacts of Air Pollution.

Emissions of air pollution may contaminate both outdoor and interior air. Humans spend the majority of their time inside. As a result, if the air breathed in inside is polluted, the residents' health is jeopardised. Indoor air pollution is responsible for 2.7% of the total world illness burden, according to World Health Surveys 2002 (WHO, 2002). Consequently, IAQ studies are required to assess the air quality of interior spaces in terms of their physical, chemical, and biological aspects, as well as the inhabitants' well-being. IAQ studies begin with the identification of indoor pollutants, their sources, and causes; the various parameters associated with IAQ, such as building parameters, occupant parameters, meteorological parameters affecting IAQ, and so on, necessitate extensive surveying, monitoring programmes, and health investigation studies. These difficulties are addressed inWhile Chapter 4 provides a general overview of indoor air pollution, including brief descriptions of indoor air pollutants, their sources and causes, various associated parameters of IAQ, monitoring and modelling of IAQ, health-related aspects and studies, and some control measures, Chapter 5 illustrates a comprehensive case study in the Indian context, focusing on emissions from biomass fuels and their health effects on women.

The case study is of particular interest since indoor air pollution caused by the use of unprocessed carbonaceous fuels such as wood, dung cake, and agricultural wastes for home cooking and room heating is a serious health problem in developing nations such as India. Over 74% of people in rural India still rely on biomass as their primary source of residential energy. Biomass fuels are very polluting, with the concentration of respirable suspended PM10 in the kitchen during biomass combustion being several times greater than vehicle pollution in cities. Toxic chemicals found in biomass smoke are hazardous to human health. Women who cook with these fuels, as well as their children, are particularly susceptible. Yet, the health effect of biomass fuel consumption in India and many other developing countries is largely unclear.

In light of this, this research was conducted to investigate the respiratory and systemic toxicity associated with persistent exposures to biomass smoke in the nation. A total of 1260 nonsmoking women (median age 38 years) from rural West Bengal (a state in eastern India) who used to make pasta exclusively with traditional biomass fuel and 650 age-matched women from the same neighbourhood who cooked with cleaner fuel liquid petroleum gas (LPG) were enrolled in the current case study. Nevertheless, as highlighted in Chapter 10, it is crucial to recognise that ultrafine particles presenting health concerns to an exposed population are caused not only by the cooking fuel but also by the cooking procedure.

Compared to LPG users, biomass fuel users had a significantly higher incidence of respiratory symptoms, decreased lung function, airway inflammation, and hidden pulmonary bleeding. The activity of the superoxide dismutase (SOD) enzyme in blood plasma was significantly reduced, indicating a drop in the body's antioxidant defence.

This was followed by an increase in the frequency of micronuclei development in buccal and airway endothelial cells, as well as comet formation in lymphocytes, indicating a greater rate of chromosomal and DNA damage. Also, airway epithelial cells from biomass users exhibited more metaplasia and dysplasia, signifying an increased risk of cancer in the airways. Moreover, biomass users had longer menstrual periods, a greater incidence of spontaneous abortions, stillbirths, and miscarriages.

as well as newborns that are underweight. They also had higher rates of depression and other neurobehavioral issues, as well as changes in reproductive hormones. 6After adjusting for possible confounders such as education, family income, and ambient cigarette smoke, the changes were shown to be closely related to indoor air pollution levels. This research discovered that using biomass fuel for household cooking is related with high levels of indoor air pollution, which has a negative impact on the physical and mental health of women who cook with these fuels. Since millions of impoverished people in the nation continue to rely on these fuels, the results call for quick action to ameliorate the situation.

Emissions of urban air pollution (e.g., from automobiles) have been shown to worsen ambient air quality across the globe and pose significant health concerns to city people. It is still a serious health problem in India due to high levels of ambient air concentrations of numerous air pollutants in Indian cities. While respiratory, cardiovascular, and genotoxic alterations are significant health consequences of air pollution, little is known about their incidence and risk among urban Indians who are subjected to some of the world's highest pollution levels. In light of this, the authors performed epidemiological studies in Kolkata and Delhi, two of the country's most polluted megacities, to study the effect of chronic exposure to urban air pollution on respiratory and other organ systems.

Urban participants exhibited a considerably greater incidence of upper and lower respiratory symptoms, bronchial asthma, and lung function impairments when compared to rural controls. Almost 40percent of respondents of Delhi residents had impaired lung function compared to 20% of matched controls, with a restrictive kind of lung function deficit predominating. Hypertension was more common in urban patients; they had more activated leukocytes and platelets in their blood, as well as a higher number of leukocyte-platelet aggregates, both of which are possible risk factors for cardiovascular disease. These participants experienced more neurobehavioral symptoms, including depression, and their airway epithelial cells showed a higher frequency of nuclear abnormality. In multivariate logistic regression analysis, the unfavourable health outcomes in urban participants were positively linked with PM10 levels in ambient air and personal benzene exposures after correcting for possible confounders such as environmental cigarette smoke and socioeconomic factors. Chronic exposure to high levels of urban air pollution in India, according to the research, is harming individuals' physical and mental health, particularly youngsters and the elderly. As a result, everyone involved should work to lower pollution levels in order to protect public health.

Megacities have evolved as economic development engines but also as extremely polluted urban air sheds, especially in developing nations. According to the 2000 census, the Mexico City Metropolitan Area (MCMA) is one of the world's most densely inhabited megacities, with 18 million residents (INEGI, 2001). On several days every year, O3 and PM concentrations in some metropolitan zones of Mexico City have been shown to be substantially over the Mexican norm. According to data from the extensive MCMA-2003 experiment, MCMA motor vehicles emit significant amounts of primary PM, particle-bound polycyclic aromatic hydrocarbons (PAHs), and a variety of air toxics such as formaldehyde, acetaldehyde, benzene, toluene, and xylenes (Molina et al., 2007). In this regard, Chapter 7 discusses air pollution exposure and health impacts identified during the MILAGRO-MCMA2006 campaign Children aged 9 to 12 and their parents were recruited from primary schools at three distinct descending sites intercepting the Mexico City air pollution plume throughout the programme.

The MILAGRO programme findings highlight the high prevalence of various subclinical manifestations associated with air pollution, despite the fact that the MCMA has recently achieved a large decrease in air pollution levels via comprehensive air quality management (Molina and Molina, 2002). The authors notice that since children are the most vulnerable persons in a population for a variety of reasons (Chung, 2001), this subgroup may be adversely impacted by many chronic illnesses if stricter restrictions and preventative measures are not implemented in this metropolitan region. Of all air pollutants, PAHs, a collection of ubiquitous persistent organic pollutants with carcinogenic, mutagenic, и immunotoxic effects, have been a growing source of worry in recent decades (especially in rapidly urbanising regions). PAH origins, distribution, chemical transformation, toxicokinetics, health concerns, and control strategies

Natural and manmade sources produce and release them into the atmosphere. Volcanoes and forest fires are natural sources, whereas high-temperature burning of fossil fuels in automotive engines, kitchen stoves, power plants, refineries, and other industrial operations are man-made sources. These pollutants have a long environmental persistence, a poor biodegradability, and a high lipophilicity. The combination of dangerous 4-6-ring PAHs with tiny particles, together with their ubiquitous occurrence in the atmosphere, makes public health vulnerable to exposure and inhalation of the aerosols.

As a result, aerosol characterisation studies have been conducted in many regions of the globe to identify PAHs in airborne particulate and analyse their environmental destiny and human exposure. A variety of PAHs are mutagenic, capable of binding covalently to DNA in target tissues, forming protein adducts, and activating aryl hydrocarbon receptor (ER)-mediated signalling. After DNA replication, mutations occur, leading to carcinogenesis. PAHs that might cause mutations have the potential to harm the germ line, resulting in reproductive issues and mutations in future generations. A single PAH has a substantially greater carcinogenic and mutagenic effect than the same PAH occurring at the same dose in a mixture, PM impacts more individuals than any other contaminant found in ambient air. Nevertheless, present information is inconclusive about the exact PM features that may be blamed for poor health effects and toxicity. Although current epidemiological research indicating that particulate matter (PM) is the air pollutant with the most persistent and significant correlations with a variety of negative health outcomes, we are still far from understanding the processes involved. As a result, focuses on the molecular processes behind the health impacts of PM air pollution. A range of variables included in the experiments described below include cell cultures of target cell types known to be relevant to organs affected by PM, as well as exposures to particles from various emission sources and of varying nature (from surrogate PM of known composition to real urban setting particles). During in vitro exposure to PM, three major biological reaction patterns have been observed: cytotoxicity (necrosis/apoptosis), cytokine generation, and genotoxicity. Nevertheless, the specific relevance of these sorts of biological responses in human health consequences has yet to be determined. Thus far, research into the impacts of diverse PM components has concentrated on identifying individual PM components that define toxicity with a specific cellular effect.

There is evidence that cellular responses are the consequence of interactions between PM components, which rise to increasingly complicated patterns of cellular responses. Generating and understanding data from PM-related mixes is an intellectual and methodological challenge. In this regard, new experiments employing concentrated ambient particles (CAPs) allow for the investigation of PM-component interactions as well as interactions between PM and gases. The authors provide experimental data linking PM exposure to respiratory and cardiovascular system damage, oxidative stress (pro-oxidant/antioxidant imbalance), and brain activation. Notwithstanding current ambiguities (exact assessment of human exposures, sample collection, harm mechanisms, etc.), the relationship between PM air pollution and human health impacts has been demonstrated. Future research should concentrate on using samples from ambient air at relevant doses in comparison to open population exposures; developing methodologies suitable for addressing multipollutants—multiple effects, as well as the ability of various Prime minister components and their interactions to convey toxicity.

a broad approach for measuring human exposure to particulate air pollution and evaluating possible health concerns with special reference to indoor airborne particles. In this chapter, case examples are provided and explored to demonstrate the applicability of this risk analysis paradigm. Cooking technique is the topic of these case studies since it is a significant source of particle air pollution in indoor spaces. The research provided in this chapter aims to analyse the possible health hazards experienced by cooks via a mix of controlled tests and real-world observations. This chapter presents both the physical characteristics (derived from controlled experiments) and the chemical properties (derived from real-world studies) of particles, as well as their relative potential risks, to demonstrate the importance of both physical and chemical properties in determining risks. The deep-frying technique releases the most particles and the largest percentage of nanoparticles, followed by pan-frying, stir-frying, boiling, and steaming. This relationship between particle number ratios and cooking techniques suggests that cooking with oil produces higher particulate emissions than cooking with water. During water-based cooking, a higher percentage of ultrafine and accumulation mode particles were identified, which is assumed to be related to the hygroscopic development of newly generated particles in the presence of high humidity.

As discussed in earlier chapters, there is considerable evidence connecting urban/rural air pollution to acute and chronic diseases and early deaths, and these negative health effects result in large societal economic costs. PM10 has been identified as a key source of health issues, notably asthma, among the many air pollutants. discusses the many sources of PM10 as well as the current levels of PM10 in major Indian cities. For 14 major Indian cities, the health consequences in terms of increased death and morbidity were assessed. According to data analysis, PM10 levels in most cities surpass 2-3 times the permitted limit of 60 g/m3. Based on 2001 PM10 concentration levels, Delhi is determined to be the most afflicted, while Bangalore is shown to be the least affected in terms of health effects. The uncertainty involved with estimating health risks underlines that PM10 levels fluctuate significantly over time, resulting in huge discrepancies in estimates. Accurately measuring pollution levels and selecting representative values are critical inputs for producing more accurate estimates. As a result, gathering systematic and accurate air quality data would be a significant step in mitigating/minimizing the negative health effects of air pollution, allowing for the development of suitable air quality management strategies/action plans.

Hazardous or hazardous air pollutants (HAPs) are classified as either "short-term or acute risk" or "long-term or chronic danger" in the environment. Short-term risk is linked with a single acute encounter with potentially hazardous compounds that have been mistakenly released into the atmosphere, while long-term risk is related with persistent exposure to potentially dangerous substances. In Chapter 12, suitable modelling tools are used to determine the acute or short-term danger of industrial hazardous chemicals being accidentally released. The models of dense gas dispersion and dose-response were employed. The model's use is proven using a case study of chlorine storage in the Indian environment. Administrators create nomograms for use after an industrial chemical disaster for evacuation reasons when immediate modelling utilisation is not necessary. The nomograms are being developed for eight of the most regularly utilised hazardous compounds in Indian businesses. This chapter also assesses the possible health concerns associated with some carcinogens and noncarcinogens (e.g., cadmium, chromium, and nickel) found in various Indian states (regions). Suitable dose-response models with assumptions and input data tailored to the Indian environment have been established and utilised for this aim. Individual and societal risks of further cancer caused by the aforementioned toxics have been assessed. The hazard quotients and hazard indexes indicating the carcinogenic and non - carcinogenic chronic health impacts of chromium and cadmium owing to long-term exposure through water and food have also been calculated.

The risk findings were compared to the disease surveillance data when a sufficient validation is seen. Furthermore, two case studies present an integrated approach to risk assessment. Throughout the nation, there are chlorine industry. Lastly, consider the present state of quantitative risk. The limits of quantitative risk assessment (QRA) methodologies are discussed. In addition to air pollution epidemiology research, international and national criteria for emissions and air quality, as well as methodologies and techniques for monitoring and modelling air pollution in order to ultimately reduce pollutants and manage air quality, are also included. It is critical to investigate the source of the air pollution issue in the first place. to deal with discusses this topic in terms of the environmental economics and public policy. interacts with several points of view, including the Neoclassical Environmental Economic

This point of view continues to have a significant effect on ideas of natural capitalism and environmental finance. Even now, Neoclassical Economic Analysis serves an important role. Each economic choice, such as spending, manufacturing, or policymaking, has a role. Cost-benefit analysis, for example, is a key public policy tool utilised in Environmental choices and rules may be made at any time. At the national, international, or supranational levels. As a result, Neoclassical Environmental For many years, economics has been at the heart of public policy on environmental challenges. decades. The debate over whether Neoclassical Environmental Economics is superior the economic approach to policy decision-making is a hotly debated topic, and There are few alternatives to Neoclassical Green Economics.

This gives insight into air pollution and its effects on health and the ecosystem, beginning with a Neoclassical Economic approach and examining the major issues alternative methods (for example, Austrian Economists, Green Economics, and Ecological Economics) Economics) in order to get a well-balanced global environmental awareness. They give a quantitative knowledge of how atmospheric chemistry, meteorology, and natural emissions impact the destiny of human emissions, the accumulation of pollutants, and the concentrations of pollutants in the atmosphere. These data may be used to calculate population exposure, measure risk, and evaluate health consequences, eventually leading to integrated models capable of evaluating the human health benefits of certain emission reduction plans. This chapter reviews current data on this topic since one of the key goals for improving air quality is to lessen human health consequences. This chapter's major emphasis is on technical elements linked to the effective creation and use of air quality systems, emission inventories, and measurement programmes, including a discussion of quantifying uncertainty. As a result, one of the main goals of this chapter is to explore how models, emission inventories, and measurements aid in air quality management, and then to address technical challenges and uncertainties in their application. Knowledge of these challenges aids in the successful implementation of these instruments, as well as in the efficient communication of their findings to air quality managers at all levels of government and the private sector

CHAPTER - 2

AIR POLLUTION MONITORING AND MODELING

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The introduction of physicochemical or biological components into the atmosphere that may cause injury or discomfort to people or other living beings, or degradation of the natural environment, is referred to as air pollution. The composition of the ambient and indoor air has a significant influence on our health and quality of life. Air pollution and greenhouse gas emissions may have a significant environmental effect, including bigger global environmental concerns like stratospheric ozone depletion and climate change. Primary and secondary air contaminants may be roughly categorised. Primary air pollutants are often compounds that are directly emitted from a natural or manmade activity, such as volcanic ash, carbon monoxide (CO) gas from motor vehicle exhaust, or sulphur dioxide (SO_2) produced from industries. Yet, main pollutants do not cause all of the negative impacts of air pollution. Chemical interactions may occur between main pollutants and atmospheric components. As a result of gaseous contaminants interacting with one other and with particles in the air, a complex array of new chemical compounds is formed. Secondary air pollutants are air pollutants that are not directly released but are generated in the air and are responsible for various negative impacts of air pollution like smog, haze, eye discomfort, and damage to flora and material.

The first stage in establishing anti-air pollution measures is obtaining a comprehensive image of the existing pollution condition via air pollution monitoring. Assessing air quality and comprehending its consequences give a solid scientific foundation for its management and control of air pollution sources. Consequently, monitoring air quality or pollution is critical in creating policies and strategies, as well as assessing compliance with permissible limits and tracking progress towards environmental objectives or targets.

Much effort should be directed to the systematic measuring of levels of air pollution at various scales ranging from local to global. Monitoring air pollution and the knowledge generated from it is not an aim in itself. Instead, it provides us with the finest method for analysing air pollution concerns, evaluating and revising environmental measures, and successfully addressing pollution problems at the local, national, and global level.

Effectively on a local, national, and worldwide scale 6The ultimate goal of air pollution monitoring is to gather trustworthy data that scientists, policymakers, and planners can use to make educated choices about how to manage and improve the overall quality of the environment (Bower and Mucke, 2004). Monitoring data, in conjunction with emission inventories and well-defined objectives, may be used to build policies that are targeted to address the most pressing problems of concern. Monitoring data that is well-presented also aids in conveying air quality concerns to local populations and ensuring that the implications of management measures are appropriately analysed. A vital component of any successful air quality management plan is high-quality monitoring data that indicates possible health or environmental consequences and tracks changes in pollution level Nevertheless, each monitoring programme has limits, and the use of analytical data from one approach should be utilised in combination with the findings of other assessment techniques, such as modelling, emission inventories, interpolation, and mapping.

Objectives of air pollution monitoring

To assess the extent to which air quality standards, limit values, and objectives are met; To assess the potential effects of air pollution on population health and welfare; To determine the impact of air pollution on ecosystems and our natural environment; and To provide the public with reliable and up-to-date information on air pollution.

To meet regulatory reporting requirements for air quality

A key stage in designing an efficient monitoring programme is determining where air quality in the area is likely to degrade or be jeopardised, and hence where monitoring should take place. The following factors may be used to identify high-risk areas:

1. Emissions sources (for example, home, industrial, transportation, agricultural, and natural) and pollutants released, as well as location and amount (areas prone to temperature inversions, etc.).
2. Topography.
3. Geograph.
4. Population centres (particularly in areas prone to household fires and transportation pollution).
5. Previous monitoring data (if available).
6. Areas with high natural environmental value (e.g., in and around natural parks, forests, wilderness, and wetlands).
7. Areas vulnerable to air pollution plumes from other areas.
8. Areas planned for development (e.g., to get a picture of background concentrations)
9. Any public complaints or issues of concern relating to air pollution.

The principal pollution sources, nitrogen dioxide (NO_2), carbon monoxide (CO), and perhaps benzene and fine particles (PM2.5), should be monitored. If the region is impacted by residential fire emissions from wood burning, particulates, CO, and polycyclic aromatic hydrocarbons (PAHs) should be measured. SO_2 levels should be monitored in areas where coal is widely used as a home fuel or by industry.

It is also necessary to evaluate if there is a guideline value or standard against which the data may be compared when choosing pollutants for monitoring. When monitoring data is compared to guideline levels, it may be determined if the pollutant is likely to produce harmful health (or environmental) impacts. For this reason, regional, national, and even international parameters are often used. Recommendations might be quantitative or qualitative in nature.

Selection of Monitoring Sites

The location of a monitoring station is closely tied to the region represented by the data. The sample location is chosen based on the monitoring program's goals. It is typically undesirable to put a monitoring station near a powerful localised source, such as a factory or garage vent, while monitoring air pollution inside an urban airshed High pollutant reading that do not normally cause issues and do not represent overall air quality in a region may be reported at these locations. Nevertheless, for specialised projects, such as identifying the link between CO concentrations at a roadside and car emissions, or between an industrial discharge and its effects on air quality, it is preferable to locate the monitoring equipment near the source.

It is also important to choose a location that is not heavily influenced by local airflows, either via shielding or funnelling. The monitoring site should represent the environment that is being or may be impacted. In other words, if unfavourable impacts on human health are a worry, the monitor should be placed where people may be harmed now or in the future. Similarly, if ecological effects are a concern, the monitor should be placed near a vulnerable ecosystem that may be impacted. It is also essential to consider the appropriate factors while choosing a location. Averaging period for the contaminant of concern guideline.

When humans are exposed to amounts beyond the recommended limit, it creates health concerns. A one-hour interval or an eight-hour period. As a result, it is proper to locate the Equipment to which individuals may be exposed for one or eight hours. Similar websites exist. situated near high traffic crossings and along traffic corridors, or inside larger metropolitan areas If home CO emissions are considerable, airsheds may be affected. on the other hand, the health consequences of benzene are often assessed during a yearly exposure period. As a result, in order to determine the total yearly dose of most urban dwellers It is ideal to place a benzene detector in a residential part in an urban region, away from the A busy road has a significant affect. This is due to the fact that, on an annual basis, individuals do not

They spend a lot of time right near to a busy road. Therefore, in order to carry out a more extensive investigation, thorough personal exposure evaluation, the monitor may be placed close the motorway. Moreover, it is critical to gather data for epidemiological research from all major places where a person may be exposed. This Indoor air or in-vehicle air might be included the atmospheric effects impacting the site should also be considered while choosing a location. The contaminant's creation and destruction. Ozone, for example, is created over time. When contaminants in the atmosphere react with one another in the presence of sunshine, the process takes time. As a result, it is necessary to monitor ozone (O_3) in areas where it is most likely to exist. present, specifically downwind from the primary precursor sources (e.g., NOx, VOCs, etc.). etc.). Similarly, NO_2 is a pollutant that is generated over time from NO emitted from combustion sources rather than being discharged into the air in substantial proportions. As a result, a monitor near a busy road, where NO has not had time to install It is possible that converting to NO_2 is not the ideal place for evaluating NO2 concentrations.

Equipment Maintenance and Inspection

Maintenance and inspection of equipment are critical for achieving accurate and trustworthy monitoring findings. The majority of air pollution monitoring equipment (including data loggers) must be calibrated on a regular basis. Instrumental bias and drift are typical characteristics. Calibration findings should be used to rectify data. A record of calibration techniques and history should be kept and made accessible upon request. Calibrations may vary from basic visual checks on equipment performance to extensive examinations of individual components and multipoint assessments on complicated contamination mixes. Calibration often entails determining if the monitoring equipment properly monitors the concentration of a pollutant in a known concentration sample. Data loggers should be used to automatically capture air quality data with as high a temporal resolution as feasible whenever practical. The accuracy and variability of multiple methods/equipment should be tested by utilising them in the same place at the same time or in separate laboratories to analyse duplicate samples. This is especially important for distinguishing various particle sampling methodologies When there is concern about the reliability or precision of a specific approach, or when alternative, less costly procedures are being considered, such comparisons should be undertaken.

Data Validation and Interpretation

Monitoring's goal is not only to gather data, but to provide information that is helpful to technical, policy, and public end-users. Raw data has virtually little use on its own. This data must first be validated and ratified before being compiled into a trustworthy and credible dataset. The interpretation of data from every air pollution monitoring station should take the site context and its consequences into consideration. A broad description of the site's features, as well as any nearby sources of air pollution, should be given. A record of meteorological variables such as airspeed, wind direction, temperature, and so on, as well as a short description of meteorological phenomena that are likely to impact air quality at the site, such as inversions and prevailing winds, should be kept.

Selection of monitoring methods

There are several ways for assessing pollutants in ambient air, each with a different cost and accuracy. Particular monitoring techniques should be selected with the purpose and goals of the monitoring programme, the available budget, and if there is a requirement to comply with any standard procedures and/or national guidelines in mind. Air monitoring techniques are classified as follows.

High-Precision Instrumental Methods

These technologies, which have a high degree of measurement accuracy, give continuous records of pollutant levels over long periods of time (weeks or months) with minimum operator interaction. These devices' detection levels are often one order of magnitude or more below average background levels in metropolitan settings. They are also the costliest monitoring systems, and proper calibration and operation are necessary to attain high accuracy. High-precision experimental approaches, such as differential optical spectra (DOAS), are often utilised in research projects or other particular investigations where it is necessary to understand how pollutant levels change over short time periods (hours or days).

Monitoring of Gaseous Sulfur and Nitrogen Compounds

The sulphur (S) and nitrogen (N) gaseous constituents that are of importance in air pollution are their equivalent oxides, hydrides, and organic compounds. SO_2 and sulphur trioxide (SO_3) are the most harmful sulphur oxides. The primary source of SO_2 is the burning of sulfur-containing fossil fuels, in which S is oxidised to SO_2 and, to a lesser degree, SO_3. The principal nitrogen oxides of concern are nitric oxide (NO) and NO_2. These contaminants may be quantified using both chemical and physical approaches. Chemical techniques for analysing gaseous sulphur and nitrogen pollutants are classed as acidimetric, colorimetric, chromatographic, and coulometric, with details available in the literature. Moreover, gaseous S and N compounds are measured using optical techniques such as chemiluminescence, fluorescence, and absorption spectroscopy.

Wittmaack and Klek (2004) define ambient aerosol as a complex combination of organic and inorganic, volatile and semivolatile, water-soluble and -insoluble materials with a variety of morphological, chemical, physical, and thermodynamic characteristics. Combustion-generated particles such as diesel, soot, and fly ash are examples of atmospheric PM, as are photochemically produced particles such as those seen in urban haze, salt particles created by sea spray, and crustal particles from resuspended dustCertain particles may be hygroscopic and include moisture-bound particles. The quantity of moisture depends on the particle composition and the relative humidity of the environment. Water generally accounts for more than half of the mass of fine air particles when relative humidity exceeds 80%. Measurements of aerial PM are often used for a number of purposes, including source attribution and assessing the efficiency of control measures.

methods, as well as research on the link between air quality and service quality. Because of the extremely fluctuating nature of airborne PM, measuring PM10 (PM with an aerodynamic diameter of 10 m) and PM2.5 (PM with an aerodynamic diameter of 2.5 m) is difficult. The exact measurement of minute quantities of mass is required for measuring the mass of PM suspended in air, whether it is ambient air PM or coal dust in mines. In general, there are two approaches to this measurement: direct microweighing techniques that determine the mass fundamentally and indirect methods that approximate the mass using other attributes of particles.

Direct Mass Measurement Techniques

Gravimetric methods are one kind of direct mass measuring methodology. Particle collection on filters is the most basic and direct sample approach. The difference in pre- and post-sample weights produces the PM mass obtained using a laboratory gravimetric balance. The mass concentration of PM may be calculated by knowing the volume of air that went through the filter. This traditional technique of weighing the deposited material on a filter is often regarded as an absolute standard.

Aerosol particle soluble parts may be removed with water and cation and anion concentrations evaluated using an ion chromatograph. For elemental composition, insoluble particles are commonly studied by instrument neutron activation analysis (INAA), protoninduced x-ray emission (PIXE), or inductively coupled plasma mass spectrometry (ICP-MS). Gas chromatography is often used to examine semivolatile components utilising an electron capture detector or one connected with a mass spectrometer [3], [4].

Individual particle bulk compositions obtained by particulate sensors vary greatly, indicating the particles' various origins and atmospheric process. There are many unknowns about the link between the mass and composition of particles collected on a filter and the real composition of PM in the atmosphere.

According to Chuen-Jinn and Hsin-Ying, sampling artefacts such as semivolatile material loss may be discovered in a variety of filter-based measuring systems (1995). Because of their high alkalinity, glass fibre filters often absorb SO_2 and HNO_3 gases, forming extraneous sulphate and nitrate in captured particle samples, producing an overestimation of both and potentially altering the reported mass of PM. This may happen inside the filter material as well as the deposited PM.

Evaporation and/or chemical processes during sampling might result in negative artefacts. 6One example is nitrate loss caused by acidic aerosol interactions, such as particulate H2SO4, with collected ammonium nitrate on the filter medium. This causes nitric acid gas to evaporate and ammonium nitrate to evaporate. Moreover, the pressure drop in aerosol sampling systems causes a fall in the gas phase concentration of certain species as air travels through the device. This results in the formation of a concentration gradient between the air stream and the particle mass, resulting in the evaporative loss of semivolatile material from the mass collected on the filter). The degree of these processes varies depending on location, as well as aerosol mass concentration and composition, as well as climatic circumstances. There have also been reports of artefacts connected with sampling, transportation, and storage One example is the loss of volatile chemicals after sampling but before weighing or chemical analysis (Chow, 1995). Additionally, the dust-loaded filter's temperature and humidity history has a significant impact on the actual mass on the filter.

Indirect Mass Measurement Techniques

The tapered element oscillating microbalance (TEOM) and beta gauge are two examples of indirect (equivalent) technologies for measuring ambient particle concentrations. Optical and filter mass transfer methods are two further examples of indirect procedures. Since there is no constant physical relationship between other particle attributes and particle mass, indirect approaches are inherently problematic.

Tapered Element Oscillating Microbalances

The tapered element oscillating microbalance (TEOM) and beta gauge are two examples of indirect (equivalent) technologies for measuring ambient particle concentrations. Optical and filter mass transfer methods are two further examples of indirect procedures. Since there is no constant physical relationship between other particle attributes and particle mass, indirect approaches are inherently problematic. By pulling a sample via a sampling inlet, followed by the sample filter, and constantly weighing the sample filter, the TEOM monitor delivers a filter-based, direct mass measurement of PM in ambient air. TEOM technology eliminates the mass calibration uncertainty that arises in systems that do not directly measure mass. Moreover, manual, gravimetric approaches remove potential filter handling errors (at both the sample site and the laboratory) while giving filter-based mass measurements in near real time. Every TEOM-based monitoring equipment is designed to enable autonomous, real-time flow control, collection conditioning, and PM mass measurement. When utilised in combination with a size-selective intake, the TEOM may be used to detect total suspended particles (TSPs) or size-fractionated PM (e.g., PM10, PM2.5, and PM1) mass concentration.

Moreover, the TEOM serves as the primary mass measuring device in a number of well-known research projects including semantics particles, fine and coarse particles, and particle behaviour. Various add-on components may be used to improve the TEOM by removing particle-bound water, retaining certain semivolatile particle constituents, or measuring total nonvolatile and volatile particle mass Nonetheless, concerns have been raised about the ability of real-time monitors to accurately measure atmospheric particles, as those operated at elevated temperatures, including the TEOM, have been reported to lose semivolatile material (Allen et al., 1997; the TEOM being 18.3% lower than the reference method across Europe).

Beta Gauge

The beta gauge is a popular continuous monitoring tool for measuring PM10 concentrations (Chueinta and Hopke, 2001). It is based on beta-ray absorption in a sample caught on filtering material, and it operates by detecting ionising radiation attenuation via particle mass deposited on a filter. It can operate unattended for lengthy periods of time and has a time resolution of roughly 0.5-2 h. The instrument's reaction is determined by the beta absorption coefficient of the particle, which varies with chemical composition. The fluctuation, however, is not very large, and this is not a severe constraint in most monitoring applications. The difference in beta-ray absorption between exposed and nonexposed filtering material, which is proportional to the mass of the trapped suspended particle matter, indicates its concentration.

Light-Scattering Instruments

Light-scattering equipment have been around for a long time, but they were mostly employed to monitor industrial dust exposures. Several of these sensors have been modified for ambient monitoring in recent years, with varying degrees of effectiveness. The "workplace" devices are inexpensive and portable, and they provide an immediate readout of initial concentration. Their measurement accuracy and sensitivity, on the other hand, are often rather low. As a result, they are only appropriate for low-level survey work. On the other hand, certain instruments are now available that provide a far greater degree of performance, to the point where they may be used in regional networks and for monitoring against ambient norms. The GRIMM aerosol spectrometer is one such machine, and the makers anticipate that it will be given equivalence status by the USEPA in the near future.

The fundamental drawback of light-scattering equipment is that their response is dependent on particle size distribution and particle number rather than overall mass of airborne particulate. This may be mitigated to some degree by performing frequent calibrations with manual filter sampling. Nevertheless, due to variations in the content and structure of airborne particles, such calibration "factors" are likely to vary between monitoring sites and seasons. Certain light-scattering sensors may also provide information on particle size distributions. This might be useful in some investigations.

Source apportionment and characterization

Identifying important pollution sources that contribute to ambient concentrations of pollutants is essential for developing an effective air quality management plan. Air quality models (see details in the next chapter) use mathematical and numerical techniques to simulate the physical and chemical processes that affect air pollutants as they disperse and react in the atmosphere. Based on inputs of meteorological data and source information such as emission rates and stack height, these models are meant to describe primary pollutants that are discharged directly into the atmosphere and, in certain circumstances, secondary chemicals that are generated as a consequence of complex chemical interactions inside the environment.

These models are critical to the air quality management system because they are frequently utilised by agencies charged with managing air pollution to identify source contributions to air quality issues as well as to aid in the creation of successful strategies to minimise dangerous air pollutants. For example, during the permitting process, air quality models may be used to ensure that a new source would not exceed ambient air quality criteria or, if required, to establish acceptable extra control needs. Air quality models may also be used to forecast future pollutant concentrations from many sources after the adoption of a new regulatory programme, allowing the program's success in lowering hazardous exposures to individuals and the environment to be estimated.

Receptor modelling comprises observational approaches that employ the chemical and physical properties of gases and particles observed at the source and receptor to both detect and quantify the existence of source contribution to receptor concentrations. They begin by measuring a particular aspect of the air pollutant, such as particle sizes, size distribution, ingredient identification, chemical state and concentration, and temporal and geographic fluctuation at the receptor, and then determine the contribution of a certain source type. The behaviour of the ambient environment at the site of impact is the subject of receptor modelling (Hopke, 1985). The basic idea behind receptor models is that mass conservation may be assumed, and a mass balance analysis can be performed to identify and apportion sources of airborne Pollution in the atmosphere.

There are two types of receptor models: microscopic and chemical approaches. Microscopic approaches identify the origins based on morphological characteristics such as wood fibre, tyre rubber, pollen, and so on (Cooper and Watson, 1980). They estimate the number of particles, density, and volume for quantitative predictions. Chemical approaches are based on the assumption of mass conservation and need knowledge of the chemical composition of both ambient and source particles. The degree of validity of this assumption is determined by the species' physical and chemical characteristics, as well as its potential for atmospheric change via processes like as condensation, volatilization, chemical reactions, and sedimentation. Chemical methods can be divided into subgroups that primarily provide quantitative information about possible sources, such as enrichment factor analysis, time and spatial series analysis, and advanced multivariate methods, whereas chemical mass balance (CMB) and advanced multivariate methods provide quantitative results about sources and are primarily used for source impact assessment studies.

Enrichment Factor (EF) Analysis

The crust and the sea are projected to be the primary natural producers of atmospheric aerosols in continental and marine locations, respectively. It is critical to compare the concentrations of atmospheric aerosol components when they are discovered to be greater than predicted in their natural forms based on their proportions in the background aerosol (earth's crust and sea) This comparison allows us to determine if certain components are anthropogenic or natural in origin. This comparison is accomplished by computing EFs for several components in the aerosol compared to the background, which are generally normalised to an element thought to be the most unambiguous sign of the source material. Since there was a limited quantity of information available, the EF technique was most beneficial. It has certain disadvantages, such as the inability to quantify a source's contribution, reliance on presumed background composition, and inapplicability to complicated source mixes when numerous sources contribute to the same element. Aerosol-crust EFs are widely used, however there is no standardisation of reference material or reference element. Since the composition of rock and soil varies from place to place, so should the aerosol produced by them. As a result, EFs estimated according to local crust may be more realistic than EFs calculated relative to a worldwide average. Calculating EFs using globally averaged crust/soil has the benefit of being standardised for all datasets, but local information might be effectively conveyed using local EFs [5].

CMB Methods

The fluctuation of components observed in a large number of samples is used by the CMB receptor approach to extract information about a source's contribution. When two or more chemicals come from the same source, their variability as a function of time measured at a receptor will be comparable. This method's goal is to find common variability and infer source identification by comparing elements with common variability to elements associated with unique sources (Henry et al., 1984).

CMB approaches detect aerosol sources by compared ambient chemical fingerprints to source chemical fingerprints (Friedlander, 1973; Kowalczyk et al., 1978). The receptor model assumes mass conservation, and the overall mass of a particular element is the linear sum of the masses of the individual species that arrive at the receptor from each source (Hopke, 1985, 1991; Watson et al., 1991).

As a result, CMB applies anytime a quantity can be described as a linear combination of other species and a mass balance equation can be formulated to account for all m chemical species in the n samples as contributions from p independent sources:

$$X_{ij} = \sum_{k=1}^{p} C_{ik} S_{kj} + E_j,$$

where xij represents the ith elemental concentration measured in the jth sample, Cik represents the ith element's gravimetric concentration in material from the kth source, and Skj represents the airborne infilled of material from the kth source contributing to the jth sample. Ej reflects random mistakes in Cik and Ski measurement, or unaccounted for causes.

Depending on the information provided, there are several approaches to solve Equation. The tracer property (Miller et al., 1972), linear programming, conventional linear least-squares fitting, effective variance least-squares fitting, and ridge regression have all been used to achieve this computation.

Equation implicitly assumes that only inert substances may be used as tracers in the CMB model. This makes using species like organic molecules as tracers challenging since they may react or deteriorate during air transmission. When a precise reaction rate constant or depreciation factor for a potential tracer is known or can be established, the mass balance equation may be adjusted to incorporate concentration degradation.

CHAPTER - 3

MULTIVARIATE RECEPTOR MODELS

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Multivariate receptor models use statistical approaches to reduce data to relevant terms in order to identify and quantify the source contributions of air contaminants. Cluster analysis, factor analysis, principal component evaluation (PCA), target transformation factor analysis (TTFA), positive matrix factorization (PMF), and Q-mode and R-mode factor analysis are some of the technologies that have been utilised for this goal. Particle composition) and gas concentration measurements have typically been the focus of these analyses because their basic assumptions appear to be the most valid for these types of measurements.

Cluster Analysis

Cluster analysis is a method for exploratory data analysis that has been frequently utilised to solve classification difficulties. This method consists of an unsupervised classification strategy that includes calculating the distance or similarity between items to be grouped. The information derived from the measured variables is utilised to identify natural clusters that exist between the samples under consideration. Items are sorted into clusters based on their similarity, with strong associations between members of the same cluster and weak associations between members of other clusters. The first assumption is that the proximity of objects in the space described by the variables indicates their property similarity.

Factor Analysis, PCA, and PMF

The data is translated into a standardised form in factor analysis by normalising the concentration of each element in each sample with regard to the element's mean value and standard deviation such that each standardised variable has a mean value of 0 and a standard deviation of 1. Factor analysis starts with an eigenvector analysis of a data cross-product matrix, most often the correlation coefficient matrix. The correlation coefficient measures how much ambient concentrations fluctuate in the same manner. If the complete variation of the variable in the system is accounted for by common components, the communality equals 1, although in most systems it is less than 1. Factor analysis varies from PCA in that the unique factor is not taken into account. Yet, neither has any restrictions on the values of component loadings or scores, but both require that the resultant components be orthogonal. PMF varies from the other two in that it needs non-negative component loadings and scores but does not require orthogonality. The absence of a non-negativity condition in PCA has the potential to provide physically illogical conclusions in the form of negative values for non-negative variables. In reality, however, this is typically not an issue since, following Varimax rotation, all scores (the quantities of the component present) that are not near zero share a single sign for each component.

They might be beneficial or negative. In reality, an effective non-negativity restriction for absolute PCA scores may therefore be implemented. It is unclear if a non-negativity requirement is always acceptable for loadings (the relative quantities of each measured species in the component). Negative loadings, for example, might indicate a species anticorrelation. For all of these reasons, it is thought that the non-negativity restriction of PMF is not a significant benefit unless physically plausible findings are produced using PCA. Both PCA and PMF, on the other hand, are capable of detecting distinct sources and their composition properties without any previous knowledge of the sources. A data matrix factor analysis may include correlation between the rows or columns of the data matrix. The approach that involves correlations between rows is referred to as "R-mode factor analysis"), while the method that involves correlations between columns is referred to as "Q-mode factor analysis." Johnson et al. (1984) also used an extended Q-mode factor analysis approach, which varies from conventional multivariate methods in that it is applied to a single sample and does not rely on concentration time correlations.

One of the most difficult aspects of factor analysis and PCA is deciding how many factors m to keep. As a general guideline, the factors should cover the greatest possible variety and offer an easy interpretation of the factors to sources. Both factor analysis and PCA have been widely used to identify sources of PM and gaseous species in many parts of the globe (Paterson et al., 1999; Vallius et al., 2003; Chan and Mozurkewich, 2007a, b). Recently, supervised PCA (SPCA), a modified variant of PCA, has been presented and employed for assessing the detrimental health consequences of various contaminants.

Target Transformation Factor Analysis

With no or very little a priori knowledge other than elemental compositional data, the TTFA model tends to extract the most information on the quantity and character of sources. This approach has been detailed by Malinowski et al. (1980) and has been applied widely in the apportionment of aerosol mass to sources. The goals of TTFA are to establish the number of independent sources that contribute to the system, characterize the elemental source profiles, and quantify each source's contribution to each sample. The number of sources is found by doing an eigenvalue study on the matrix of sample correlations.

The degree of overlap between an input source and one of the computed factor axes is determined by a target transformation. Input source profiles, known as test vectors, are created using prior knowledge of emission patterns from different sources. Unique test vectors are also evaluated, with one element's value set to 1.0 and all other elements' values set to 0.0. The uniqueness test may resolve sources indicated largely by a single element. A weighting method has been introduced to the analysis to give each piece similar relevance in the desired transformation. For each datum point, the weighting factors are the estimated variance of the element multiplied by the experimental error. The weighted rotation considerably improves the target transformation's ability to resolve source with comparable concentration profiles.

Multiple Linear Regression

Multiple linear regression (MLR) is a procedure that is similar to CMB in that it is based on a linear least-squares fitting process. It is necessary to identify a tracer element or property for each source category, and it is assumed that the quantity of tracer in the sample is proportional to the source intensity at the receptor. It is applied to the observed total mass with tracers acting as independent variables. Tracer element or property selection is often dependent on knowledge of emission sources and their compositions, which may be reinforced by factor analysis**.**

There are several devices and methodologies available for doing direct or indirect air pollution monitoring. There are also several receptor models available for detecting sources of air contaminants and determining source contributions. Among the methods used for this include factor analysis, PCA, PMF, and TTFA, as well as multiple regression in combination with these approaches. Since their fundamental assumptions seem to be the most appropriate for these sorts of data, these studies have generally concentrated on particle composition and gas concentration observations. The composition data is sometimes separated into coarse and fine particle fractions. Many efforts have been made to add particle size information in these investigations in order to get greater understanding into particle origins. A few research used factor analysis methods on datasets with comprehensive size distribution data. PCA or PMF has been employed in a number of investigations. It has been discovered that the inclusion of relevant input data and the proper application of the approach is more significant than the exact method utilised in order to generate meaningful result.

Air Pollution Modeling Theory and Application

Models of air pollution are useful tools for policymakers because they may be used to link emissions and concentrations. In addition, since data are often sparse, models may be used to estimate concentrations when there is no information. When combined with demographic data, models may easily be utilised to predict exposure and, ultimately, health impacts. Estimating the charges of emission reductions and the economic advantages of decreased health and environmental consequences may be used as a foundation for cost-benefit analysis of emission regulations, pollution prevention programmes, or day-to-day mitigation techniques in the proper context. For a long time, air pollution modelling has been used to support both long-term and short-term policy.

Forecast models, for example, are used in the short term to inform the public about potential poor air quality in the coming days and have even been used to decide whether real-time pollution abatement strategies are implemented, as in the case of Santiago and Temuco in Chile. Long-term, air quality models are used to assess the impact of pollution-reduction strategies in support of studies on emission standards and on attainment of air quality standards in both developed and developing countries. When nonattainment of particulate matter is found by monitoring stations in Chile, dispersion models are utilised to delimit the region where particular emission rules will be implemented. It is crucial to highlight, however, that for models to be utilised to support policy choices, they must accurately reflect "reality.

Atmospheric dispersion basics

In its most basic form, an emission source striking the atmosphere may expand horizontally and vertically by a phenomenon known as dispersion, and the shape drawn out is roughly conical and known as a plume. The plume's spread will be determined by the climatic circumstances (wind velocities, for example) and process conditions (temperature of emission, plume rise velocity, and so on) present in the atmospheric boundary layer. Temperature variation with altitude effects turbulence characteristics and consequently pollution dispersion. The temperature of the atmosphere is determined by incoming solar radiation, wind velocity, and cloud cover percentage. The magnitude of these characteristics determines the classification of atmospheric circumstances: class A, very unstable; class B, moderately unstable; class C, slightly unstable; class D, neutral conditions; class E, somewhat stable conditions; and class F, moderately stable conditions. For example, very low wind speeds (i.e., 2 m/s) combined with exceptionally intense incoming solar energy will result in exceedingly unstable situations (class A). There has been a lot of study done to provide more information on the categorization of various stability levels in the atmosphere and how they affect dispersion.

Dispersion modeling and types of dispersion models

Simple Gaussian models clearly cannot be utilised to represent more complicated circumstances. Several ways have been created throughout time to accommodate additional processes and time variable situations. Models were first used to forecast the downwind concentration of pollutants, which is important for assessing the environmental effect of existing or planned new sources in accordance with local air quality requirements. These models are useful tools for establishing effective control measures that minimise hazardous air pollution emissions. The dispersion models require data input, which may include the following: meteorological conditions such as wind speed, wind direction, temperature (which affects reaction kinetics), sunlight and cloud cover (which affects photochemistry), and rainfall (which affects wet removal processes); emission parameters such as source location and height, stack diameter, exit velocity, exit temperature, and mass flow rate; terrain elevation at the source location (locatability); and terrain elevation at the exit location (locatability).

In addition to the aforementioned factors, nonhomogeneous and unstable circumstances have an impact on air dispersion. To cope with such issues, Nema and Tare (1989) stressed the need of using computational simulation processes. These authors created a collection of computer programmes based on Zannetti's (1986) methods to cope with (i) a single steady and continuous source, (ii) numerous steady and continuous sources, (iii) calm wind circumstances, (iv) light wind conditions, and (v) transport conditions. Although categorising dispersion models as analytical or numerical is one option, it does not seem to be a universally recognised categorization. As a result, it is necessary to investigate the many kinds of dispersion models found in the literature. Holmes and Morawska (2006) provided a comprehensive analysis of dispersion modelling, and most of the information in is replicated here with permission from the publisher.

These models may be used to represent dispersion on a local scale (for example, street canyons, local stack impact, and so on) as well as urban and regional-scale phenomena (interactions of multiple source categories and even the interaction between emissions from different cities). Chemistry is also represented differently. While gas-phase chemistry is widely understood, modelling particle concentrations and numbers includes more complicated mechanisms involved in aerosol chemistry and aerosol dynamics.

Box Model

The most fundamental model is the box model, which is mostly based on mass balance. Although its transport treatment is simple, the chemistry involved may be somewhat complicated. The location is idealised as a box in this case. Pollutants discharged into the box undergo physical and chemical transformations. Simple meteorology and emissions are also required for the box model. Pollutants are permitted to enter and exit the box. It is believed that the air mass within the box is well mixed. It may feature more extensive and complicated gas and particle response schemes that can be evaluated in a box model before being added into more complex models. Nevertheless, well-mixed and homogenous circumstances are not always achievable. These models should be used with the understanding that they do not reflect big regions or circumstances that are not included in the model [6], [7].

Gaussian Plume Model

Gaussian-type models are commonly employed in regulatory atmospheric dispersion modelling. This model is based on the Gaussian distribution of the plume in the vertical and horizontal directions during steady-state circumstances, as detailed in the preceding section. Most Gaussian models simply address pollution diffusion and advection. Gaussian models have been expanded to incorporate physical processes such as deposition and quick chemical reactions. These models, too, assume a uniform wind pitch. Despite various shortcomings, Gaussian plume models are often used because to their simplicity:

1. The steady-state assumption: In this case, models do not account for the time it takes for the pollutant to get to the receptor.

2. Gaussian models are unsuitable for regional particle modelling, owing to their simplistic consideration of secondary aerosol production.

3. The Gaussian equation can't account for recirculation effects induced by several buildings or junctions.

Gaussian Puff Model

Puff models are capable of handling both temporal and geographical fluctuations in meteorological domains. This is accomplished by approximating continuous emissions from sources with a series of discrete puffs advected along the prevailing wind vector and growing at a rate proportional to the state of atmospheric turbulence There are two methods: puff superposition and segmented plume The computation of pollution dispersion, transportation, and removal is conducted in a moving frame of reference attached to a number of parcels as they travel across the geographical area of interest, in accordance with an observed and computed wind pitch. The plume grows in proportion to the square root of the downwind distance, while the puff grows in proportion to 3/2 the power of the downwind distance. Puff algorithms are made up of the following steps:

Varangian Model

The Lagrangian method is based on tracing the motion of a fluid particle to investigate its properties. Box models and Lagrangian models are extremely similar. A box is defined as the area of air carrying an initial concentration of contaminants. The box is assumed to be moving, and the model follows its motion. When contaminants migrate from one location to another, the dosage is the product of the source term and the probability density function. This model accounts for variations in concentration caused by mean fluid velocity, wind component turbulence, and molecular diffusion.

Lagrangian models are effective for both homogeneous and stationary circumstances on flat ground and inhomogeneous / unstable media situations on complicated terrain. Lagrangian models are very useful for studying the forward and backward trajectories of emissions, which are accessible from the Norwegian Institute for Air Research (NILU) and the National Oceanic and Atmospheric Administration (NOAA), are two of the most well-known Lagrangian models. This is mostly due to its ease of use and ability to operate on web-based tools.

Commercial and open-source software

The preceding section explained the fundamental components and methodologies of dispersion modelling. Although there are numerous open-source models available, they are not necessarily user pleasant. A significant amount of commercial software has been built utilising the various concepts outlined above. Specific models are sometimes provided for free, although simple programmes are commercially available. The US Environmental Protection Agency (USEPA) has established a list of recommended and preferable dispersion, photochemical, and receptor models in its Technology Transfer Network Support Center for Regulatory Modeling.

It is critical to understand both the capabilities and limits of current software. A short-range model that does not include photochemistry, for example, cannot be utilised to study ozone generation. We divided the presentation into two broad categories to show the evolution of a large number of software: software that excludes the specialised treatment of aerosol dynamics and software that incorporates aerosol dynamics. We propose to summarise briefly the available software under the subheadings of Box, Gaussian, Lagrangian, and CFD models in the first category.

Software Excluding Aerosol Dynamics

Box Models

Modeling Air Quality in Urban Areas Using an Optimal Resolution Method (AURORA): The concentration of inert and reactive gases and particles has been represented using this concept. The model estimates pollution concentrations inside a street canyon. It assumes a consistent concentration across the street. Within the box, convections in both the x and z directions are considered. CPB (Canyon Plume Box): This model was designed by the United States Federal Highway Administration to analyse concentrations inside roadways and is suited for street canyons with height-to-width ratios between 0.5 and 2 (Yamartino and Wiegand, 1986). The model computes the equilibrium load of inert gases and NO2 in the atmosphere.

Photochemical Box Model (PBM): A more complex box model that simulates photochemical smog at the metropolitan scale (Jin et al., 1993). In the presence of sunshine, the model is appropriate for low and changeable wind conditions. It is assumed that emissions from point, line, or area producers are spread uniformly throughout the box's surface and that the volume inside the box is properly mixed.

Gaussian Models

CALINE4 (California Line Source Dispersion Model): This model was created for regulatory reasonsIt is used to address traffic emissions by spreading them as an endless line source separated into a sequence of perpendicular to the wind direction parts. Vertical dispersion parameters take both thermal and mechanical turbulence created by vehicles into consideration. Nevertheless, since it is a Gaussian model, it is not suggested for modelling at low wind speeds, cannot be utilised for short distances, and does not have the capacity needed for modelling in street canyons.

OSPM (Operational Street Pollution Model): The Gaussian plume equation is used to compute the direct contribution from the source, and a box model is used to evaluate the influence of turbulence on the concentration. Inside the plume, crosswind diffusion is ignored, and the sources are viewed as infinite line sources. The model assumes that transportation emissions are dispersed equally over the canyon. It is unable to simulate intermittent oscillations in wind flow and, as a result, is not recommended for computing concentrations on timeframes less than 1 h; it really does not take cooling of the exhaust plume after emission into account.

The California Puff Model (CALPUFF) has been used to study gas and particle dispersion. It can represent four different kinds of sources: point, line, area, and volume, utilising an integrated puff formulation that incorporates the effects of plume rise, partial penetration, and buoyant and momentum plume rise. It is not advised for calculations with durations less than 1 hour or when turbulence has a significant impact on dispersion. AEROPOL is a steady-state dispersion model with inert gases and particles that extends up to 100 kilometres from the source. It may be utilised for local-scale dispersion and includes correction for building impacts. It is only suitable for flat terrain applications. The model incorporat6es a plume rising method based on Briggs' calculations (1975). Dry and wet deposition are calculated as functions of deposition velocity and rain, respectively.

The California Puff Model (CALPUFF) has been used to examine gas and particle dispersion. It can represent four kinds of sources, namely point, line, area, and volume, utilising an integrated puff formulation that incorporates the effects of plume rise, partial penetration, and buoyant and momentum plume rise. It is not advised for calculating timeframes less than 1 hour or if dispersion is substantially impacted by turbulence. AEROPOL is a steady-state external origin for inert gases and particles up to 100 kilometres from the source. It may be utilised for local-scale dispersion, and it also includes treatment for building impacts. It can only be used on level terrain. The model contains a plume rising algorithm based on Briggs' equations (1975). The model estimates dry and wet deposits as a function of deposition velocity and precipitation, respectively.

UK-ADMS (UK Atmospheric Dispersion Modeling System): Carruthers and Holroy (1994) created this model for the dispersion of buoyant or neutrally buoyant particles and gases. It forecasts the structure of the boundary layer using a similarity scaling technique to that of Berkowiicz et al (1986). Screening Version of the ISC3 Model (SCREEN3): The USEPA created this well-known and widely used model (1995). It is used for logistical reasons to determine concentrations from industrial emissions up to 50 kilometres away. It is capable of calculating the influence of basic elevated terrain as well as the 24 h concentration owing to plume impaction in complicated terrain.

Lagrangian/Eulerian Models

The Graz Lagrangian Model (GRAL) is used to simulate the dispersion of inert substances in heterogeneous wind environments. The model predicts concentrations from 10 minutes to 1 hour for line sources, point sources, and tunnel portals in flat and difficult terrain (Oettl and Sturm, 2005). (Oettl and Sturm, 2003). It is assumed that the plume rise in the region of the tunnel portal is constant as a function of the temperature gradient between ambient air and tunnel flow. The model's weakness is that it fails to account for secondary aerosol production.

ARIA FARM (Flexible Air Quality Regional Model): ARIA FARM was created to investigate the dispersion of gases and particles from industrial, transportation, and area sources up to 1000 km away with a resolution of 1 to 10 km (Silibello et al., 2008). As a result of the thermodynamic parameters of gases, ARIA can handle multi- and single-constituent isothermal and nonisothermal gas flows. The ARIA regional model employs two theoretical techniques that enable the user to choose the best dispersion model for the application:

FARM, which is based on the Eulerian approach, and SPRAY, which is based on the Lagrangian approach. FARM is used to determine the concentration and deposition of reactive emissions between 50 and 1000 kilometres, including photochemistry gases and particles. SPRAY, which focuses on particle emission, is used to assess the concentration and deposition of nonreactive emissions across complicated terrain. This model has been used in Europe for both policy-oriented and operational air quality forecasting.

CFD Models

The Microscale Flow and Dispersion Model (MISKAM) may be utilised for specialised purposes in urban-scale modelling, such as including buildings and even landscaping (Balczo et al., 2009). The model does not support steep terrain. It also excludes thermal effects, buoyant release, and chemical interactions. MICRO-CALGRID (Microscale California Photochemical Grid Model): This is an urban canopy-scale photochemical model that makes use of the MISKAM model's flow fields and turbulence. MOBILEV, a traffic-induced emission model, and horizontal and vertical advection and diffusion techniques are all included. Dispersion Model for the Atmospheric Transport Modeling System (ATMoS): ATMoS is a three-layer forward trajectory Lagrangian puff-transport model at the mesoscale. As part of the Regional Air Pollution Information System for Asia, the model was created for simulating sulphur pollution (RAINS-Asia). It was widely used in Asia for sulphur and particle modelling studies at the regional, national, and urban levels.

The model's temporal and spatial resolution are both adjustable. The horizontal spatial resolution for an urban-scale investigation may range from 1000 m to 1° 1° (90 km) for a regional-scale study. Nevertheless, because of the advection techniques used, which tend to simplify the coupling between horizontal and vertical layers, this model is not suggested for episodic study. The model is suited to investigations at the regional and urban levels, examining seasonal and yearly air quality for long-term trends and evaluating "what-if" scenarios. The model is performed for sulphur, nitrogen, and particle pollution individually. Due to physical and chemical variations in PM10 and PM2.5, two different bins with variable dry and wet deposition functions are separated for particles. In addition, sulphate and nitrate concentrations are added to the PM10 and PM2.5 fractions to account for secondary particle contribution

Eulerian and Lagrangian Models

GATOR is a Eulerian dispersion model that estimates the dispersion of gases and aerosols in urban-scale (Jacobson, 1996, 1997) and mesoscale settings (Lu and Turco, 1997; Jacobson, 2001). It supports the Eulerian dispersion technique and may use either a moving or fixed size particle dynamic module. The model also estimates solar irradiance, which is required for estimating photo dissociation from particle and gas scattering and absorption curves. MO stands for Multimono Operational Highway Pollution Model.

Korhonen and Lehtinen (2004) created this size-segregated aerosol dynamics model, the University of Helsinki Multicomponent Aerosol Model (UHMA). The model is intended to encompass aerosol dynamics treatment, with an emphasis on new particle creation and growth. Particle growth is dependent on both coagulation and condensation it onto particles. The model's coagulation treatment is based on Brownian motion, which is the primary factor responsible for submicrometer particle coagulation, and is regenerated as a function of particle size at each time step. California Institute of Technology (Caltech)/Carnegie-Mellon Institute of Technology (CIT): This model is intended to simulate dispersion and chemistry inside an air shed and combines Pilinis and Seinfeld's aerosol model (1988). It employs a sectional approach to particle size distribution (with three size sections ranging from 0.05 to 10 mm) and aerosols made of organic and inorganic components. It is based on the assumption that aerosols are in thermodynamic equilibrium. Russell's processes were used to represent gas-phase chemistry (1988). Secondary organic aerosol production is thought to be caused by three different sources: aromatics, diolefins, and the cyclic ethenes cyclopentene and cyclohexene.

The URM-1ATM (Urban-to-Regional Multiscale—One Atmosphere Model): The CIT mode has been updated in this model. Model of the California Photochemical Grid (CALGRID): Based on the UAM-IV (Urban Airshed Model with Aerosols version 4) model, this model is an Eulerian dispersion model with enhancements to horizontal advection (Yamartino and Scire, 1989), vertical transport, deposition, and pyrolysis (Scire and Yamartino, 1989). The model employs horizontal grid sizes ranging from 500 m to 20 km and vertical grid sizes ranging from 20 m to 2 km to generate domain sizes ranging from 20 to 1000 km horizontally and up to 10 km vertically in order to calculate the hourly concentration of both reactive and inert gases and particles within a complex terrain.

Stability categories are used to determine atmospheric stability and boundary layer height. The plume rises of floating sources in a stable, neutral, or unstable atmosphere is computed using the Briggs technique (1975). This model predicts secondary petrol production using the photochemical pathway SAPRC.

Sulfur Transport Eulerian Model (STEM) at the University of Iowa: This model was originally developed to study regional sulphur transport for acid rain regulatory purposes (Carmichael et al., 1991), but it has since been widely used for chemical weather modelling and forecasting because it incorporates meteorologically driven size-resolved primary emissions of sea and dust aerosol, as well as secondary formation of inorganic aerosol. It employs the SAPRC-99 chemical mechanism for lumped species. It has also been used to assess the interactions of aerosol species with photochemistry. Lastly, it has been widely utilised to assess the regional export of secondary pollutants from megacities, such as ozone or sulphur. This approach has been used to analyse and enhance emissions inventory estimates in the United States. Because of recent advancements in an affine version of the model, it is now one of the first comprehensive chemistry inverse models.

CHAPTER - 4

STATISTICAL/PROBABILISTIC AIR QUALITY MODELS

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Although the fundamental idea of air quality models has been known for some time, deterministic models have only recently been employed to support emission permits and policy applications. Significant developments in processing power have made them valuable for predicting air quality. Its effectiveness, however, is restricted by the quality of their inputs: meteorological modelling, emission inventory estimates, boundary conditions, and their portrayal of complicated phenomena (such as wind-driven releases of seawater).

Research examined the effectiveness of deterministic models versus statistical models on ozone modelling and found that statistical approaches continue to outperform deterministic models (Comrie, 2006). Prediction analyses have been created with the goal of forecasting concentrations only based on observations. The two basic forms of statistical models are regression and neural network models. The first kind of model uses correlations to predict future concentrations. Tomorrow's PM concentration, for example, may be associated to today's air quality and certain climatic parameters. Multiple variable regressions are used to estimate these associations. Neural network models, on the other hand, "learn" from prior experience, linking tomorrow's prognosis with the result of comparable patterns and trends. Statistical models are simpler and have fewer possibilities of model error than deterministic models, but they do not give information on the mechanisms that generate air pollution. Their model results are often discontinuous in both time (only predicting maximum concentrations, no time series) and geography (only providing information on sites where measurements were obtained). Model inputs such as emissions inventories or episodic occurrences are not explicitly included into statistical models (such as wind storms, biomass burning, etc.)

Artificial Neural Network Models

The ultimate purpose of any modelling effort, as stated in the prior sections, is to compute the concentrations of a particular pollutant for a known set of input data. Clearly, the equations of continuity, momentum, energy, turbulence, chemical processes, and so on must be solved in deterministic models. Depending on the size of the grids and the scale of the models employed, computational requirements will rise. Assume one is interested in calculating air quality at a few kilometres from the polluting source. This requires calculations for the full flow domain, including the point of interest where air quality is required. An artificial neural network model (ANN), on the other hand, may do this task considerably more readily provided it is trained using some known findings. To grasp the potential of ANN, we must first provide a quick overview. Later, we will look at an example that demonstrates why its usage is significant to the topic of air quality modelling.

ANN is a sophisticated soft computing technique that is extensively utilised in pattern recognition, dynamic prediction, control, and optimisation. Artificial neurons are the processing hubs that carry out information processing. Signals are sent between units through connection connections. Each connecting link has a weight that denotes its strength, and each node often performs a nonlinear modification to its net input to produce its output signal, known as an activation function. The neural network's architecture reflects the pattern of connections between nodes, the mechanism for generating connection weights, and the activation function. The nodes are organised into three layers: input, concealed, and output. The input layer accepts input variables and sends them to the network. The network's anticipated values are represented in the output layer. The nodes in one layer are linked to the nodes in surrounding layers but not to the nodes in the same layer.

The inputs are represented as an input vector X = (x1, x2, x3,..., xN), and the appropriate weights are written as wij. Yj = f(XWj - bj), where bj is the threshold value and is referred to as bias, X is the input vector, and Wj is the weight vector. The function f is referred to as an activation function. Its functional form dictates how a node responds to the overall input signal. The sigmoid function is the most widely used version of the function. It is necessary to train and verify the ANN model. As a result, the datasets are separated into training and testing datasets. Following training using the training dataset, the ANN model should be verified with the testing dataset. If the ANN model reproduces the testing dataset with adequate accuracy, it might be judged suitable.

If there is no mathematical link between the variables, neural networks are best suited. Since the link between the variables in the system is not precisely understood, the ANN model may be used to the domain of temporal interpolation of air quality. The number both input and output nodes are determined by the issue. The number of layers that are hidden has a major impact on network performance. Also, the inaccuracy during training might be affected by the scale of outputs (Ojha and Singh, 2002). With too few nodes, the network will approximation poorly, and with too many nodes, this will overfit the training data. As a result, the best design is usually determined by trial and error.

Fuzzy Logic-Based Modeling

Fuzzy theory has also been used to rank air quality models. As a result, it is thought acceptable to provide a short overview of fuzzy logic (FL), which is pertinent to the work recounted here. Zadeh's fuzzy set theory has been used to describe uncertain or noisy information in mathematically It has been used for a variety of reasons in engineering, business, psychology, among other fields. It is a superset of traditional (Boolean) logic that has been modified to accommodate the idea of partial truth-truth values ranging from "totally true" to "absolutely false.

It is an easy approach to translate subspace to output space. A fuzzy set is one that lacks a clearly defined boundary. The membership function, which depicts numerically the degree to which an element belongs to a set, is the core idea in fuzzy set theory. For example, if an element is partially a member of a fuzzy set, the value of its membership value may range between 0 and 1, as determined by removing the sharp border separating set members from nonmembers (Klir and Foger, 1988). Many fuzzy sets reflecting linguistic notions, such as low, medium, and high, are often used to describe the state of variables, which are referred to as fuzzy variables. FL must be a useful and practical approach for modelling a complicated phenomenon that may not yet be completely understood due to its capacity to cope with imprecise, unclear, or ambiguous data or connections across datasets.

Ranking of Models

Statistical approaches may be used to rate atmospheric dispersion models.bYet, determining a model's supremacy over all other models is difficult since each form has its unique functional qualities. As a result, developing a mechanism for picking an acceptable model is important. Park and Seok describe a model to anticipate plume dispersion in coastal locations for a better understanding (2007). Input data from a coastal region near a power plant in Boryeung, Korea, are used to test several modelling methodologies. The input data consists of meteorological data from 1.5 to 60 m in height, including upper air temperature and pressure along with altitude and 1-hour SO2 concentration data.

The first step of this method is to identify eight dispersion modelling schemes applicable to complex coastal areas by taking into account the presence of fumigation phenomena and thermal internal boundary layers, and then the performances of each modelling scheme in the prediction of 1-h SO_2 complex coastal terrain were also roughly reviewed using up to eight statistical measures. The statistical score is computed as a single index in the second phase using fuzzy inference, and the optimal model is selected by comparing the indices. Fuzzy inference is employed to give a single index based on multiple statistical variables for picking an acceptable scheme among eight fumigation modelling systems. Variables are represented here by a triangle or trapezoid membership function. By defuzzifying the output, the inference findings are quantified into multiple scores.

Establishment of Membership Functions for Premise Variable

As variables of the premise section, many statistical measures are used. There are six of them: fractional bias (FB), normalization mean square error (NMSE), geometric bias mean (MG), geometric bias variance (VG), within a factor of two (FAC2), index on agreement (IOA), unpaired accuracy of peak concentration (UAPC), and mean relative error (MRE) (MRE). By examining evaluation criteria on metrics offered by numerous investigators, membership functions are classed as excellent, fair, or bad based on model performance level.

Time Series Analysis

Accurate predictions of contaminants as a function of time are required for locations prone to high pollution concentrations so that those impacted by pollutants may organise their activities ahead of time. Moreover, previous awareness of excessive pollution levels may be utilised to reduce emissions on time via traffic rerouting and the closure or control of certain industrial units. Air pollution may be forecasted using the quantity of data available. Statistical methodologies may be utilized successfully for creating and evaluating such an accurate forecasting system.

Model Identification Process

The process of selecting the best model is a step-by-step process. While the majority of time series probability theory is concerned with stationary time series, time series analysis necessitates converting a nonstationary series to a stationary one. Logarithmic, square root, or power transformations are often used to stabilise the variance in a series. First-order differencing is frequently required if the calculated autocorrelation coefficients fall slowly at longer delays. Iterative model construction begins when the series is rendered stationary by correct transformation. Based on the form of the autocorrelation function and the partial autocorrelation function, a preliminary model may be constructed. At this point, one must select how many autoregressive and moving average parameters are required to produce an effective yet frugal model of the process. Parsimonious implies it has the fewest characteristics and the most degrees of freedom of any model that fits the data.

Estimation of Parameters

Choosing the best model is one step-by-step process. Since much time series probability theory is concerned with stationary time series, time series analysis necessitates converting a nonstationary series to a stationary one. Logarithmic, square root, and power transformations are commonly used to stabilise the variance in a series. If the calculated autocorrelation coefficients fall slowly at longer delays, first-order differencing is frequently required. Iterative model construction begins after the series is rendered stationary by suitable transformation. Based on the form of the autocorrelation function and the partial autocorrelation function, a preliminary model may be constructed. At this point, one must determine how many autoregressive and moving average parameters are required to produce an effective yet frugal model of the process. Parsimonious indicates that it has the fewest components and the largest number of degrees of freedom among all models that match the data.

Estimation of Parameters

An Iterative approaches such as Newton's method, the steepest descent method, or the Levenberg-Marquardt method are used to estimate the parameters. The sum of squared royalty payments is minimized in these approaches. Diagnostic tests are used to determine the model's statistical adequacy. This is accomplished by examining the residual series for interdependence. If the residuals s does not meet the diagnostic criteria, the model should be modified and the parameters re-estimated. This procedure of reviewing residuals and modifying parameter values is repeated until the resultant residuals have no further structure. An autocorrelation function plot of residuals is one of the statistics used for diagnosis: If all of the autocorrelations and partial correlations are modest, the model is suitable for predicting. In addition, the model should aim to minimise the sum of squared residuals.

Using CALMET + CALPUFF to Define Geographical Extension of Nonattainment Areas

Estimating the geographical extent of nonattainment zones is a regular exercise for regulators. This sort of investigation is initiated when a certain region's air quality criteria is exceeded. Nonattainment is usually inferred when a monitoring station's three-year median exceeds 50 g/m3 or when the 98% percentile of 24-h PM10 surpasses 150 g/m3. Dispersion models are commonly used in Chile to analyse the geographical region that is in nonattainment (where emissions are restricted according to a pollution prevention plan). This is accomplished by simulating a complete year of PM10 concentrations using the region's presently accessible emissions inventories, which include mobile sources, household sources, and regional industrial sources. Universidad Católica completed this study at the request of CONAMA. Similarly, CONAMA examined the role of certain significant industrial sources (smelters and power plants) in Chile's nonattainment of the SO2 96 ppbv 24-h mean air quality standard. Episodes were modelled in CALMET CAMx for this unique air quality Tracers were also used to estimate source contributions, which enabled determining the particular contribution of a big point source to the overall observed values. depicts the elevated SO2 levels measured.

Using WRF-Chem for Regional Modeling of Ozone in Chile

WRF-Chem has been employed in Chile for analytical work in terms of individual source contributions to air quality issues, notably ozone. The study also looked at the interconnections between regional pollution sources (industrial, urban, and so on). Universidad of Chile developed the paradigm for the Chilean Department Of Environment Commission, CONAMA (Schmitz et al., 2008). Complete chemical analysis was performed from January 1 to 15, 2008 (high-ozone season), using a 4-km resolution, 115 127 grid, 36 vertical levels, 15-s integration time step, and hourly outputs.

The mean maximum concentrations for Central Chile. These findings were useful in demonstrating that the highest ozone concentrations in Santiago were situated northeast of the city, outside the range of ozone detectors. This research was particularly significant in indicating that the development of tropospheric ozone in Santiago was mostly controlled by volatile organic compounds (VOC), which is crucial for understanding the design of ozone pollution management measures. A sensitivity test designed to assess the influence of a given power plant on ozone production. The difference in ozone concentration with and without the point source is used to compute this. In this example, the big point source reduces ozone generation locally (perhaps owing to titration), whereas ozone formation rises farther downwind from the source. According to source apportionment studies, the following are the principal sources of PM pollution during the dry season (October to March):

(a) vehicle emissions, notably motorcycles, diesel trucks, and buses (the most prevalent sources in both fine and coarse modes); (b) soil and road dusts resulting from civil construction, broken roads, and open land wind erosion; and (c) biomass burning in brickfields and municipal incinerators (to the fine mode).a summary of the source apportionment analysis for fine and coarse mode particles undertaken by the Bangladesh Atomic Energy Center in Dhaka, Bangladesh, at two stations: the farm gate and the Dhaka University premises [8], [9].

The study was carried out utilising "GENT" stacked filtered samplers, followed by PIXE analysis of the filter samples and PMF receptor modelling (Guttikunda, 2009a). The research involves the creation of city-specific source profiles, which give the biomarker information needed to identify sources, evaluate measured samples, and estimate the percentage contributions of distinct sources.

It is crucial to highlight that the findings of the source apportionment cannot be generalised to the whole city, but they do give a foundation for additional study and knowledge of the mix of sources contributing to air pollution, particularly near hot spots. The source apportionment procedure utilised in this research is costly, preventing the inclusion of numerous measurement sites, in contrast to a mobile monitoring site, which can Motor vehicles are a well-known and visible source of particle pollution in Dhaka, necessitating technical (emission requirements) as well as institutional measures (inspection and maintenance). Dust from road resuspension, an indirect source of motor vehicle activity, is a significant contributing factor to air pollution (in the coarse mode of PM) due to a lack of enough infrastructure (paved roads) to support rising fleets and traffic congestion.

Brick kiln clusters north of Dhaka generate 40% of the observed fine PM pollution. Increasing building activity (which contributes to fugitive dust) is driving up demand for brick kilns, while the combustion of biomass and low-quality coal pollutes the environment. The bulk of the brick kiln clusters are to the north of the city, and the observed peak values indicate the worst-case scenario with the highest wind blowing into the city (the dark grey line limit). There are 530 brick kilns in the clusters.

It is crucial to remember that these are estimates, and a more thorough study is necessary, which is often performed as part of the feasibility studies before and after project execution. The calculations take into account the control measures that are now under pilot implementation and estimate that the majority will be operational by 2020, as planned. In 2020, the total health and carbon benefits were estimated to be about $472 million (IES, 2008). The DRFs for outdoor pollution and the approach presented in HEI (2004) and Guttikunda (2004) are used to assess the health consequences (2008b). The monetary value of the health benefits, including mortality and morbidity attributable to outdoor air pollution, is based on the "willingness to pay" technique, and the carbon benefits are valued at $20 per tonne of CO2 decreased. The combined benefits of integrated pollution levels and climate change policies are expected to make significant improvements in the city by 2020 (or earlier, depending on feasibility and accelerated actions) and, given time, technical, and financial support, the implementing measures will lead to a better urban environment.

Linear Regression Models in Santiago, Chile

Both Santiago and Temuco surpass the daily and yearly PM10 air quality guidelines of 150 and 50 g/m3, respectively. The Chilean Environmental Commission (CONAMA) has developed a novel technique to reduce air pollution, limiting emissions based on the findings of a statistical prediction model. For example, if air quality is expected to exceed 195 g/m3, wood-burning warmers and stoves are prohibited from usage. If levels exceed 240 g/m3, an extra 40% of automobiles are taken off the road, and companies that do not satisfy a 32-mg/m3 PM pollution threshold cannot function for 24 hours. Daily, model findings and emission limitations for the next day are announced in national news sources.

The capacity of the model to reliably forecast these contingency levels is the only criterion for model performance. Model prediction errors spark considerable debate (Global Post, 2009), since overprediction of events may compel Santiago residents to rely on public transit, or industry to shut down. The media usually ignores model underprediction of air pollution. Joe Cassmassi created the model in the 1990s. It is a statistical multivariate regression model that links anticipated air quality values with current measurements and forecasted meteorological factors, which are termed air quality predictors. The model result is generally the maximum 24-h mean PM10 expressed in g/m3 for each of Santiago's air quality measuring sites (Perez, 2008). Synoptic-scale characteristics, findings from a radiosonde along the shore, and certain anticipated metrics generated from global prediction methods are among the meteorological parameters included in the prediction. These characteristics are combined to form a single parameter known as the Meteorological Potential for Air Pollution (PMCA).

at 1-hour intervals, which are utilised for training and validation of the chosen network. For longer time period air quality data, if the input neurons are three, the data is converted into input vector X[x1, x2, x3] (preceding, current, and successive). If the input neurons are four, one more neuron was obtained from the prior week's data for the present time of the same day. The number of disintegrated intervals for the current measurement interval corresponds to the number of output neurons required for dissolving air quality data. The period of the disintegration data is 8, 4, 3, and 2 h intervals, resulting in an output neuron count of 8, 4, 3, and 2, respectively. A preliminary study of related training mistakes is used to calculate the number of hidden neurons. The unipolar sigmoid function was chosen as the activation function for the feed-forward ANN model.

Deterministic and statistical air quality models have long been utilised for policy implications. Gaussian plume models are being used decades ago to analyse the dispersion of massive sources. Eulerian and Lagrangian models are now more widely accessible. Improvements in scientific knowledge and computing power, together with lower costs, allow a regional air quality prediction model to be performed on a single unit, double quad core processor system; a decade earlier, the same operation would have required hundreds of processors. Air quality models may be used to assist environmental regulators by delimiting locations that do not meet certain air quality criteria.

Models, in conjunction with observations, may be used to assess the contribution of individual sources to air quality measures. Models can assess the contribution of a given source to the production of regional photochemical smog (such as ozone and particulates). Lastly, innovations in inverse modelling enable systematic improvements in model performance and estimate of emissions inventories using approaches such as 4DVar data assimilation. As shown in a case study in, the combination of models and policy analysis may be utilised to determine the advantages of adopting certain pollution abatement measures.

India. Lastly, air quality may be mathematically projected using statistical models like artificial neural networks or regression models. Although these models have greater correlation than deterministic models in predicting maximum pollution, they do not give information about the processes involved in pollution, especially emissions, limiting their relevance in policymaking. Hopefully, future estimates of emissions inventories will increase, as will the coverage of air quality data. Deterministic models will be employed at that time to provide strong and trustworthy air quality predictions and diagnostics, which can be used to further create public policy in order to limit human exposure to pollution in an expense way.

CHAPTER - 5

AIR POLLUTION AND HEALTH EFFECTS

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Throughout time, man has developed more intricate structures to shield himself from the elements such as rain, snow, warm air in the summer and chilly air in the winter. Nevertheless, such structures do not always protect residents from indoor pollutants. A person spends 90percent of total of his time inside structures (Hoppe and Martinac, 1998). As a result, the interior environment might be considered as a "habitat" or a "ecology." It is a complex "habitat" comprised of multiple qualities, including inhabitants and their activities, air routes and ventilation, the building shell, and its surrounding contexts. As a result, understanding the link between interior and outdoor habitats is essential. According to scientific research, the air within buildings may be more contaminated than the outside air, generating difficulties linked with poor indoor air quality (IAQ). Indoor air pollution is responsible for 2.7% of the worldwide illness load.

Indoor air pollution began with the usage of fireplaces in caves. The concerns with indoor air quality were undeniably more visible back then than they are now. Soot discovered on the ceilings of ancient caves gives clear evidence of the high levels of pollution associated with poor ventilation of open fires (Spengler and Sexton, 1983). When chimneys first appeared in European dwellings in the late twelfth century, most big mediaeval buildings still featured a central hearth in the great hall, vented by a louvre in the roof. Chimney stacks were not widely used until the fifteenth century (Brimblecombe, 1987; Burr, 1997). The blackened roof timbers in many houses that precede these developments bore witness to the serious pollution issues that their residents experienced. Nevertheless, prehistoric people had many more problems than health dangers, and little attention was devoted to IAQ until the early 1920s. The earliest systematic research on IAQ, undertaken in the 1920s and 1930s, focused on calculating how much ventilation was required to maintain a suitable mix of metabolic gases.

Indian Perspective

In the poor world, indoor air quality (IAQ) affects 90% or more of our lives at home, work, and in transportation. Biomass fuel (wood, dung, and agricultural leftovers) is utilised for heating and cooking in 75% of Indian homes. It accounts for 80% of home energy usage in India. This fuel is primarily utilised in open flames or basic stoves, mainly inside and with little to no ventilation or chimneys. This circumstance results in some of the highest amounts of indoor air pollution ever documented, to which small children and women are exposed daily for several hours. Every year, this exposure kills half a million people prematurely. According to the World Health Organization (WHO), indoor air pollution caused by biomass smoke is one of the most significant environmental risk factors for all types of illness.

Indoor Air Pollution: Their Sources and Causes

IAQ is defined as "air in an inhabited place towards which a considerable majority of occupants express no discontent and in which there are not expected to be known pollutants at concentrations that constitute a significant health risk" (ASHRAE, 1989). The indoor air quality is directly related to the outside air quality. Nonetheless, inhabitants and their activities contribute to the generation of pollutants in interior environments. IAQ is determined by a variety of variables and the interplay of "sources," "sinks," and air flow between rooms and between the building and the outdoors.

Indoor air pollutants are a diverse group of elements that include gases, vapours, and particles. The identification of health impacts connected to these contaminants collectively, individually, or in specific combinations requires considerable information about an individual's exposure to this mixture. The major indoor air pollutants that affect human health are broadly classified into three categories: particles, vapours, and gases, and their sources are broadly classified as building occupants' activities and other biological sources; partial oxidation of substances for heating or fuel; and emission levels from building materials.

IAQ is defined as "air in an occupied place towards which a considerable majority of occupants express no discontent and in which there are not likely to be known pollutants at concentrations leading to exposures that constitute a serious health risk" (ASHRAE, 1989). The IAQ is strongly related to the outside air quality. Yet, inhabitants and their activities also contribute to the generation of pollutants in interior areas. IAQ is determined by a variety of variables as well as the interplay of "sources," "sinks," and air flow between rooms and between the building and the outdoors.

Indoor air contaminants are a complicated mixture of gases, vapours, and particles. The identification of health impacts associated with these contaminants collectively, individually, or in specific combinations requires considerable information about an individual's exposure to this mixture. The major indoor air pollutants that affect human health are broadly classified into three categories: particles, vapours, and gases, and their sources are mainly categorised as the activities of building occupants and other biological sources; combustion of substances for heating or fuel; and emissions from building materials.

They are often caused by wet or surface walls, floors, ceilings, and mattresses, as well as by badly maintained air conditioners and humidifiers. About 3800 chemicals, including VOCs, inorganic gases, and metals, are found in environmental tobacco smoke (ETS), many of which are carcinogenic or may exacerbate the carcinogenic qualities of other contaminants. "Sinks" are high-surface-area or porous places where odour or other gaseous impurities settle. They may be found in rooms or systems and may eventually become secondary sources. Air movement in a building is comprised of (a) natural air movement among rooms, which is sometimes aided by occupant movement, (b) air movement driven by a forced air system, namely an HVAC system; air movement between the building as well as outside via ventilation, infiltration, and exfiltration; and air movement driven by elevator piston action, the thermal stack effect, and air pressurisation differentials.

Poorly built ventilation systems and airtightness in buildings may result in a "inadequate" supply of fresh air. As a consequence, negative pressure builds up, which may attract outside contaminants inside buildings via vents, cracks, and gaps. Indoors, uncontrolled temperature and humidity levels may produce odour and bioaerosols (fungi, moulds, and other disease-causing bacteria). The indoor pollutant flow in depicts the contaminant's "life" in the structure. Bioaerosols, particles, VOCs, and both inorganic and organic gases are examples of indoor air pollutants.

Airborne microbiological particulate materials generated from viruses, bacteria, mites, pollen, and their cellular organ cell mass components are known as bioaerosols. Both indoor and outdoor surroundings include bioaerosols. Floors in hospitals may act as a reservoir for organisms that are then re-entrained into the air. Although carpeting looks to effectively trap germs, circumstances inside the carpet may enhance their survival and spread. Even via aerosolization, water has become an established source of infectious pathogens (Figure 5.1).

Particulates are a large range of biochemical pollutants observed as discrete particles in the air. They are characterised as solid or liquid particle mixes or dispersions. Dust, smoke, fumes, and mists are common examples of particles. They are divided into two categories: suspended particulate matter (SPM) and respirable particulate matter (RPM) (RSPM). The Environment Agency (EPA) has classified RSPM as particles of 10 mm or smaller in size (PM10).

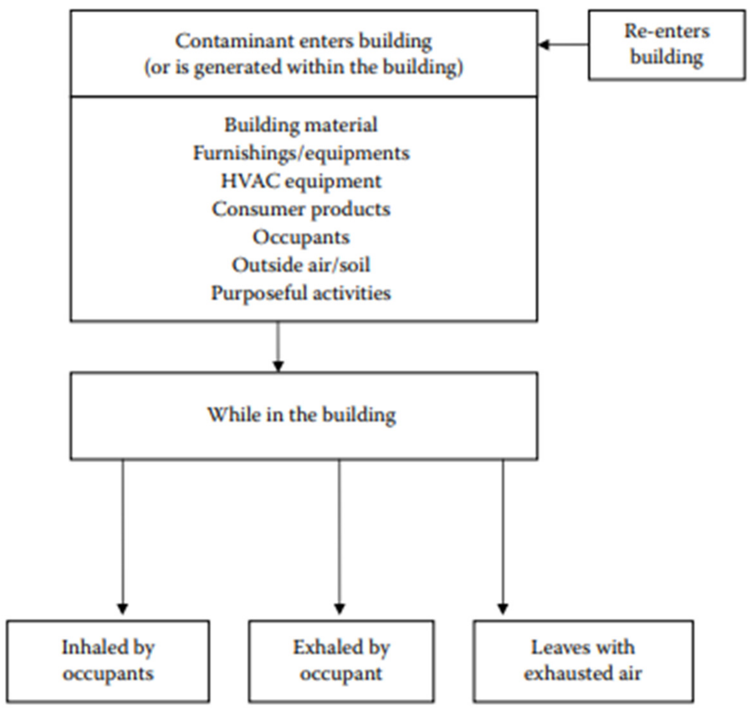

Figure 5.1 Represent the Indoor air pollutant flow.

They are the principal cause of lung cancer and are available in diameters as small as 2.5 mm (PM2.5) and 1.0 mm (PM1.0). Particulates at workplaces are produced as a consequence of work-related activities such as adding batch components for a manufacturing process, spreading asphalt in a roofing activity, or drilling an ore deposit in preparation for blasting. Because of ambient pollution, the external environment is a primary source of particles. This source enters the building through ventilation, infiltration, or occupant traffic. Particulate sources in the interior environment may include cleaning dirt buildup in carpets and other fleecing sources, building and renovation waste, paper dust, and deteriorating insulation. Indoors, the most typical sources of RSPM are ETS, kerosene heaters, humidifiers, wood stoves, and fireplaces.

In typical room temperature and relative humidity (RH), the VOCs exist as a gas or may readily off-gas. All nonindustrial indoor spaces include a variety of VOCs. VOCs are often the first worry when identifying an IAQ issue, after ventilation. The list of probable VOC sources is extensive and expanding. Wet emissions, which have very high emission rates when first applied, can be found in newly constructed buildings, photocopying material, carpets, wall coverings, and furnishings, refrigerants, gasoline, cosmetic products, biological matter, moulded plastic containers, disinfectants, cleaning products, and ETS. Although direct VOC emissions from primary sources predominate, certain materials behave as emissions sinks before becoming secondary sources by re-emitting adsorbed compounds. Floor dust, which differs from dust in the air, has indeed been discovered to be both a main and a secondary source of VOCs.

Nitrogen oxides, sulphur oxides, carbon monoxide (CO), carbon dioxide (CO_2), ozone (O_3), and chlorofluorocarbons are examples of inorganic gases (CFCs). Nitrogen oxides are mostly produced by kitchen equipment, pilot lights, and unvented heaters. Underground or linked parking garages may potentially add to interior NOx concentrations. An unvented petrol cooker emits around 0.025 ppm of NO2 into a household. Nitric oxide is a colourless, odourless, and tasteless gas. NO inhalation results in the development of methemoglobin, which has a negative impact on the body by interfering with oxygen transport at the cellular level. Nitrogen dioxide is a corrosive gas with a strong stench, with a reported odour threshold of 0.11 to 0.22 ppm. Since NO_2 has a poor water solubility, it may be breathed into the deep lung and trigger a delayed inflammatory reaction.

Sulfur dioxide (SO2) may be produced by kerosene space heaters, the breakdown of fossil fuels, or the combustion of any sulfur-containing substance. SO_2 is a colourless gas with a strong odour at roughly 0.5 ppm. Since SO_2 is very soluble in water, it may react with moisture in the upper respiratory system to induce irritation of the mucous membrane. Contaminant exposure to fine particles, an individual's depth and rate of breathing, and the existence of underlying illness may all impact the degree of SO_2 toxicity.

CO is an odourless, colourless, and tasteless gas created by incomplete hydrocarbon combustion. Gas stoves, kerosene lamps and heaters, tobacco smoke, wood stoves, and unvented or inadequately vented combustion sources are all common indoor CO sources. CO is a chemical suffocator. CO inhalation creates a throbbing headache due to CO's competitive preference for haemoglobin. Carbon monoxide hinders oxygen delivery in the blood by causing carboxy haemoglobin to develop.

Human breathing generates CO_2. It is not typically thought of as a harmful air pollutant, although it may act as a simple asphyxiant. When CO_2 is measured at isotherm and with occupant densities of 10 persons per 100 m2 floor area, a level of 1000 ppm has been proposed as being reflective of supply rates of 10 L/s per person of outside air. CO_2 may be hazardous not just as a poisonous substance, but also as a secondary asphyxiant. CO_2 may produce headaches at values ranging from 2500 to 5000 ppm. People lose consciousness in 10 minutes at exceptionally high levels of 100,000 ppm, and at 5 million ppm, CO_2 causes partial or total closure of the glottis.

O_3 is produced as a result of electrical or coronal discharges from office equipment such as laser printers and photocopiers. At doses of around 0.12 ppm, ozone is a lung irritant that induces alterations in human pulmonary function. At 60-80 ppb, ozone produces inflammation, bronchoconstriction, and enhanced airway reactivity. CFCs are halogenated alkaline chemicals that have been employed in refrigeration applications as heat transfer gases, as blowing agents and propellants in aerosol goods, and as expanders in plastic foams. Chronic, low-level CFC inhalation exposures may induce cardiotoxicity. Chronic 1000 ppm exposure for 8 hours per day for up to 17 days resulted in no subjective complaints or changes in respiratory function.

VOCs include formaldehyde. It is a common chemical found in a broad range of goods and is widely employed in the construction of new structures. At room temperature, it is a colourless gas with a strong odour at higher concentrations. The infiltration of outdoor air is one source of formaldehyde in the indoor environment, but the primary sources are within the building itself: building materials (thermal insulation in building side walls, plywood and particle board, floor coverings, and carpet backing), combustion appliances (gas stoves and heating systems), tobacco smoke, and a wide range of consumer products (paper for wax paper, facial tissues, napkins, and paper towels).

Asbestos is a common structural component in schools, residences, and private and governmental structures. Its release in the interior environment is influenced by the stiffness of the asbestos-containing material (ACM) and the magnitude of the disturbing force. Asbestos and related fibrous minerals have been employed in building materials, consumer goods, and appliances. The most common applications for ACM include boiler insulation, pipe soundproofing, sprayed-on fireproofing, breaching insulation, and floor and ceiling tiles [10], [11].

ETS is released by the burning end of cigarettes, cigars, and pipes, as well as second-hand smoke inhaled by smokers. Breathing in ambient ETS is known as passive or accidental smoking. Tobacco combustion pollutants are classified as either mainstream smoke or sidestream smoke. Sidestream smoke is inhaled by both smokers and nonsmokers. Mainstream smoke is unadulterated and is drawn into the smoker's lungs along with the tobacco. Sidestream smoke is produced directly from the combustion of tobacco. The composition of mainstream smoke exhaled by the smoker changes significantly depending on smoking habit, burning temperature, and filter type.

Smoking is the leading cause of indoor particles (of varying composition) and a variety of unpleasant gases. When tobacco does not entirely burn, various toxins such as sulphur dioxide, ammonia, nitrogen oxides, vinyl chloride, phosgene, formaldehyde, radionuclides, benzene, and arsenic are released. Odors are a kind of gaseous pollutant that may cause pain, irritation, tension, complaints, and even fear, panic, and mass hysteria. They are caused by tenants, and their consequences are mostly concerned with comfort rather than health. As a result, tracking down odour complaints is very difficult, and facility managers often push odour concerns to the bottom of the priority pile. Cooking, smoking, toilet usage, and upkeep all produce scents that are frequently annoying and, in some circumstances, noxious. Almost all construction materials and furniture emit odours to various degrees.

Radon and its offspring are the only naturally occurring radionuclides in the atmosphere. The series, which starts with radon-222 and concludes with the alpha decay product of radon-226, is generated by the decay of radium, which is formed by the disintegration of uranium.

Radon is a noble gas that may migrate away from its source, giving it a good chance of reaching air that people breath. It is an odourless and colourless gas that is constantly present in the air at varying amounts. Radon's short-lived decay products, polonium, lead, and bismuth, are chemically active and may therefore be collected in the lungs directly or by particles to which they adhere. Before they can be swallowed, 90% of radon daughters adhere to bigger airborne particles. The greatest significant dosage is produced by the alpha decay of the polonium isotope. Building materials, soil, and ground water are the primary sources of radioactive particles and radiation. It generally penetrates structures via cracks, gaps, or other breaches in the foundation. The soil parameters, building factors, and pressure differentials all have an impact on radon flow.

Air temperature and humidity are two of the six key comfort factors that determine the quality of the interior environment and are essential indicators of IAQ. They are also crucial to the occupant's impression of IAQ. The hot and humid environment of India may have an unfavourable effect on the residents' comfort. As a result, managing air humidity and temperature is the most important component in creating comfort in interior situations. The temperature of the air in a confined room normally rises from the floor to the ceiling (vertical temperature gradient). If the temperature difference is high enough, a person's head may experience local warm pain and/or cold discomfort at the feet even though the general average temperature is thermally neutral. To avoid this local discomfort, the standard specifies a maximum temperature differential of 3°C (5°F) between the head and the feet. To minimise discomfort in confined places, humidity levels should be kept below 55%, or, more precisely, below a dew point of 62°F. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 55-2004 (ASHRAE, 2004a) specifies a temperature range of roughly 67°F to 82°F for thermal comfort.

Ventilation and IAQ

The "supply of adequate amounts of outside air in the building for the inhabitants to breathe and to dilute the concentration of pollutants created by the people, equipment, and materials within the structure" is referred to as ventilation. It is critical in maintaining excellent indoor air quality. It influences the residence duration of pollutants inside and the movement of pollutants between indoor and outdoor settings. The longer the residence duration of pollutants, the lower the ventilation rate. The pollutant concentration within the spaces is inversely related to the ventilation rates, which means that double the ventilation rate reduces the pollutant concentration by half.

Both mechanical HVAC and naturally ventilated structures need it (Awbi, 1991). IAQ issues mightbe caused by a poorly constructed HVAC system. Bacteria, viruses, mould, and other biological pollutants are often found in locations that supply food and moisture or water. These organisms thrive in humidifiers, condensate pans, and improperly maintained HVAC equipment.

The temperature climate has been demonstrated to influence occupant discomfort and efficiency. The HVAC system regulates the indoor heat conditions. Energy conservation measures for limiting outside air intake and improving airtightness in building designs may have negative health consequences for building occupants. The successful operation of such systems is dependent on adequate maintenance; otherwise, it may result in the appearance of building illness, or sick building syndrome (SBS). As a result, a properly planned, built, operated, and maintained HVAC system may improve indoor air quality. Moreover, because of the existence of moveable ports, grills, vents, and unexpected airflow under varied climatic situations, natural ventilation is unregulated.

The airflow within naturally ventilated structures is caused primarily by pressure and temperature gradients, which are influenced further by two driving forces: (1) thermal buoyancy (stack pressure) and (2) wind pressure. The airflow in naturally ventilated structures is also affected by the form and scale of the building, the placement and orientation of openings in relation to their sizes and wind direction, the surrounding roughness, building layouts, terrain, and so on. It is also affected by climatic elements such as wind speed and direction, interior and outdoor temperatures, and relative humidity. Higher ventilation rates may, in theory, reduce the concentration of indoor pollutants in such buildings; however, higher penetration of outdoor pollutants may occur because of unsanitary conditions, such as uneven air distribution or insufficient exhaust ventilation. The problem worsens when outside pollution concentrations are greater or indoor pollutant sources present. As a result, in order to comprehend the importance of ventilation in "acceptable" IAQ, (ASHRAE updated its ventilation standard.

pressure and temperature gradients, which are further influenced by two driving forces: (1) thermal instability (stack pressure) and (2) wind pressure. The airflow in naturally ventilated structures is also affected by the building form and size, the placement and orientation of openings in relation to their sizes and wind direction, the surrounding roughness, building arrangements, terrain, and so on. It is also affected by climatic factors such as wind speed and direction, interior and outdoor temperatures, and relative humidity. Higher ventilation rates may, in theory, lower the concentration of interior pollutants in such structures; nonetheless, more penetration of outside pollutants may occur owing to uncontrolled factors such as uneven air distribution or inadequate exhaust ventilation. The situation deteriorates more when outside pollution concentrations are greater or indoor pollutant sources present. As a result, in order to comprehend the relevance of ventilation in "acceptable" IAQ, (ASHRAE updated its ventilation standard. Happens in a structure in which a fraction of the residents suffers varied degrees of nonspecific illness or discomfort dominated by sensory responses." (1) building occupants' complaints of symptoms associated with acute discomfort (e.g., headache; eye, nose, or throat irritation; dry cough; dry or itchy skin; dizziness and nausea; difficulty concentrating; fatigue; and sensitivity to odours) are indicators of SBS, (2) the cause of the symptoms is unknown, and (3) most complainants report relief soon after leaving the building. Inadequate ventilation, chemical pollutants from indoor sources, chemical contaminants from outdoor sources, biological contaminants, and psychological variables such as perception of temperature, aural, and visual surroundings are all causes of SBS. SBS patients frequently describe nonspecific symptoms that cannot be reliably assessed, and they usually exhibit no clinical indicators of disease. SBS symptoms are associated with building occupancy since they improve after leaving the building. Although though complaints are persistent and symptom incidence among occupants is substantial, with up to 80% of employees reporting at least one symptom, IAQ studies of ill buildings often fail to detect pollution concerns (Wilson and Hedge, 1987).

Sampling/Monitoring and Modeling of Indoor Air Pollutant

Continuous, integrated, and grab or spot sampling are the three primary types of sampling procedures. Continuous sampling allows for real-time monitoring of concentration variations over short time periods. Integrated sampling takes an average sample over a certain period of time. When the mean concentration is either desired or appropriate for the purpose, it is employed. Grab sampling yields single samples obtained at predetermined intervals. It typically consists of admitting an air sample into a previously evacuated vessel, drawing a sample into a deflated bag for later analysis, or drawing a sample through a sample collector (via a mechanical pump) to extract a contaminant from air; it is appropriate when "spot" samples are adequate for pollutant measurement and knowledge of temporal concentration variation over short periods is not required.

For different contaminants, multiple sampling procedures are available. Gravimetric analysis methods are used to sample particles in mass based on their diameters. The principal sampling approaches established for gaseous contaminants are roughly characterised as passive (based on membrane permeation or diffusion over a geometrically specified air space) and nonpassive (in which air pumping devices pull volumes via known collection efficiency devices).

The concentration of a pollutant indoors is determined by the relationship between the volume of air contained in the indoor space, the rate of pollutant production or release, the rate of pollutant removal from the air via reaction or settling, the rate of air exchange with the outside atmosphere, and the concentration of the pollutant outdoors. Numerical models may be used to determine the amount of indoor air pollution; mass balance equations are used to estimate interior pollutant concentrations as percentages of outside concentrations, as well as infiltration rates, indoor source strengths, pollutant decay rates, and mix factors. Estimating overall human exposure to pollutants (exposure to pollutants encountered inside and outdoors, at industrial sites and other workplaces, etc.) requires knowledge about not just pollutant concentrations, but also individual patterns of movement and time usage. Yet, quantifying real human doses is often problematic. This is primarily due to the fact that people' behaviour and activity habits may have a significant impact on their amounts of exposure.

Indoor air pollution and health effects

Many variables influence the health impacts of inadequate IAQ. When calculating possible health consequences on a community, the effect of each air pollutant, concentration/exposure limit, period of exposure, and individual sensitivity are all important factors to consider. The air pollutant might be an allergy or a carcinogenic agent, causing an instant response with low long-term consequences and cancer years later, respectively. Building occupants are exposed to about 100,000 hazardous compounds; nevertheless, exposure limits exist for fewer than 400 industrial chemicals. The Occupational Safety and Health Administration (OSHA), the US Environmental

Protection Agency (USEPA), and the World Health Organization (WHO) have established exposure limits for some of the most common indoor air contaminants. The possible health effects and limitations of contaminants often detected in indoor air. Non-occupational conditions are covered under the USEPA and WHO criteria. The criteria are designed for 8-hour exposure to outstanding and good class IAQs. The duration of exposure is particularly important in assessing IAQ exposures. Exposure in office buildings is typically 8-10 hours per day, five days a week.

Exposure in residential structures can last up to 24 hours a day, seven days a week. Because some substances accumulate in the body over time, 24-hour exposure may result in a buildup of pollutants and their subsequent impact on health. As a result, a given concentration of air pollution has a lower effect in business buildings than in dwellings. Other places to look for potential long-term exposures include hospital patient rooms, hotels, mental wards, and prison cells. Individual sensitivity adds a significant component to the mix of variables influencing building occupant health. Infants, the elderly, and the sick are the most vulnerable to the health effects of air pollutants. Immune weakened people, such as AIDS patients and organ transplant recipients, as well as those with hereditary illnesses, such as Lupus erythematosus, are more vulnerable to common moulds. Individuals who consume excessive amounts of alcohol are more vulnerable to air contaminants that can harm the liver.

have a weaker bodily defence mechanism. There is consistent evidence that indoor air pollution raises the incidence of pneumonia in children under the age of five, as well as chronic respiratory illness and lung cancer (in connection to coal consumption) in individuals over the age of 30. The evidence suggesting a relationship between biomass smoke and lung cancer, as well as a link between biomass smoke and asthma, cataracts, and TB, was deemed moderate. Based on the few studies that have been conducted, there is questionable evidence for a link between indoor air and unfavourable pregnancy outcomes, namely low birth weight, ischemic heart disease, and nasopharyngeal and laryngeal malignancies. Indoor air pollution has two types of health consequences: short-term (immediate and/or acute) effects and long-term (cumulative and/or chronic) effects.

Short-term effects may appear after a single or several exposures. They include eye, nose, throat, and skin irritation, as well as headache, dizziness, and tiredness. If they are discovered, they may be treated. Most of the early consequences are similar to those of a cold or other viral sickness, making it difficult to tell whether the symptoms are caused by indoor air pollution. As a result, it is essential to pay attention to the time and location where the symptoms appear. Only after prolonged or repeated exposure to contaminants can cumulative effects arise.

Indoor air pollution has been linked to a variety of health outcomes, with evidence ranging from strong to moderate to questionable, according to a recent systematic review. The majority of air contaminants have a direct impact on the respiratory and cardiovascular systems. Elevated levels of SO2, SPM, or RSPM have been linked to increased mortality, morbidity, and reduced pulmonary function. Although the exact process by which exposure causes illness is unknown, it is known that tiny particles and various other pollutants found in indoor smoking promote inflammation of the airways and lungs, as well as impairing the immunological response.

Conjunctivitis, acute respiratory nervousness, and acute respiratory infection are some of the acute and subacute health impacts of inhaling biomass smoke (ARI). Chronic obstructive pulmonary disease (COPD), chronic bronchitis, cor pulmonale, unfavourable reproductive outcomes and pregnancy-related difficulties such as stillbirths and low birth weight, and lung cancer are all long-term impacts of inhaling biomass smoke. One research in Western India found a 50% increase in stillbirths among pregnant women who were exposed to indoor smoking. Similarly, research in Africa found that cooking with wood significantly raised the chance of stillbirth. Carbon monoxide levels in the bloodstream of women cooking with biomass in India and Guatemala have been shown to be high. Research in India, Nepal, and Papua New Guinea demonstrate that nonsmoking women who have cooked on biomass stoves for many years showed a higher incidence of chronic lung illness (asthma and chronic bronchitis) (asthma and chronic bronchitis). Women exposed to wood smoke for many years in Mexico had a 75-fold increased chance of developing chronic lung disease, around the same level of risk as regular cigarette smokers, then women who were not exposed to wood smoke. According to a recent Colombian research, women who were exposed to smoke while cooking were three times more likely to develop chronic lung problems. Indoor air pollution has been demonstrated in studies in South America and India to significantly impair lung function in children.

There is increasing concern that second-hand cigarette smoke exposure poses a major and significant public health danger. Cigarette smoke comprises about 3800 chemicals, including Polycyclic aromatic hydrocarbons, inorganic gases, and metals, many of which are carcinogenic or have the potential to exacerbate the carcinogenic qualities of other pollutants. Young toddlers and newborns who are exposed to passive smoking are more likely to develop lower respiratory tract and inner ear infections. The health consequences of airborne particulates are determined by various parameters, including particle size, durability, and dosage. In certain cases, extremely little doses may induce negative health impacts (hazardous exposures), whilst other apparently enormous exposures have no negative effects (nuisance exposures). The health risk from particle air pollution is calculated using the mean risk per unit ambient concentration and is based on the findings of various urban epidemiological research (Smith, 1996). The risk range was determined to be 1.2-4.4% higher mortality every 10 mg/m3 additional rise in respirable suspended particle concentration (PM10).

CHAPTER - 6

DISPROPORTIONATE IMPACTS ON CHILDREN AND WOMEN

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Home energy methods differ greatly over the globe, as does the mortality toll caused by indoor air pollution. Although more than two-thirds of indoor smoke-attributable fatalities from acute lower respiratory infections in children occur in WHOE's African and South East Asian regions, the Western Pacific area accounts for more than half of COPD deaths owing to indoor air pollution. Women are in charge of cooking in most countries, and depending on the needs of the local cuisine, they spend between 3 and 7 hours each day near the cooker making meals. As a result, females account for 59% of all fatalities caused by indoor air pollution. Little children are often carried on their mothers' backs or kept near to a warm fire. As a result, throughout their first year of life, when their maturing lungs make them most exposed to dangerous contaminants, newborns spend several hours inhaling indoor smoke. As a consequence, children under the age of five account for 56% of all indoor air pollution-related fatalities. In addition to the health impact, fuel collecting may be time consuming for women and children. Eliminating this task would free up women's time for productive undertakings and child care, as well as increase children's school attendance and homework time.

IAQ and Health Effects: Indian Estimates

Indoor pollution from conventional biomass fuels is responsible for half a million fatalities in India each year. India and China account for around 60% of developing-world solid fuel-using households, implying that household solid fuel usage is responsible for nearly two million premature deaths globally each year. Indoor exposure would represent for 4-6% of the worldwide illness burden, depending on the number of young children in total. In contrast, it is believed that urban air pollution is responsible for 1-2% of the worldwide illness burden. According to these estimations, the health effect of indoor exposure would be greater than the burden of all but two other significant avoidable risk factors: hunger (15%) and a lack of good water and sanitation (7%). It outnumbers the worldwide burdens of sexually transmitted illnesses, cigarettes, illegal substances, hypertension, occupational risks, alcohol, war, traffic accidents, and murder. Except for total ARIs, diarrhoea, and the paediatric cluster of vaccine-preventable illnesses, it surpasses the world burden for several diseases (measles, diphtheria, tetanus, polio, and pertussis). If these figures are correct, the worldwide burden of illness caused by indoor air pollution is greater than that caused by TB, AIDS/HIV, malaria, heart disease, or cancer.

ARI is the single greatest illness category in the world (approximately one-twelfth of the global disease burden); in India, it accounts for almost one-eighth of the disease burden. For young children, the odds are 2-3. (10 studies in developing countries). Premature deaths range from 290,000 to 410,000. Chronic bronchitis, for example, accounts for roughly 1.5% of fatalities among Indian women. For women who have been cooking over biomass fires for 15 years, the odds are 2-4. Premature deaths range from 19,000 to 34,000. Cooking over open coal stoves has been related to lung cancer in women, but there is minimal evidence of a relationship with biomass fuel. The odds ratio for over 20 Chinese studies is 3-5. Early deaths range from 400 to 800. Blindness is connected to the use of biomass fuels by women in India, which has the world's highest incidence of blindness. This group's odds ratio is 1.15-1.3. Blindness does not result in early death, but it does impose a severe cost of impairment. Tuberculosis accounts for 5% of the Indian disease burden, a higher rate than in any other area. It causes 50,000-130,000 premature deaths. Perinatal consequences (stillbirth, low birth weight, and mortality or sickness during the first two weeks after birth) account for 8.8% of the Indian disease burden. Nevertheless, there is insufficient information to draw estimations concerning early mortality. Cardiovascular diseases (CVDs) and asthma are recognised to be linked to outdoor air pollution and passive smoking in developed nations, but not in developing-country homes.

The WHO health bulletin reported the findings of Smith and Schwela's studies on the number of deaths caused by indoor particle pollution in developing and developed countries for both rural and urban populations; the findings show that particle pollution is responsible for 67-68% of total deaths caused by indoor particle pollution in rural households. This is because biomass fuel is used for cooking and heating. Before date, only a few similar studies on developing-country rural populations have been conducted.

Indoor air pollution control

In reality, there are little distinctions to be made between contamination control and treatment and mitigation. Addressing an existing issue by mitigating or remediating it is often the same as taking preventative actions to manage it in the first place. Thus, once treated, the same treatment becomes a preventative measure to avoid recurrence. Certain preventative measures that are not accessible in remedial therapy may be used (e.g., building design). Building owners and facility managers must comprehend the numerous reasons of managing the quality of indoor air to satisfy tenant demands. First and foremost, federal regulations for particular contaminants must be followed. Nevertheless, complying with rules that lack legal authority may nonetheless be legally wise as a defence against carelessness in possible claims. The fundamental goal of all control processes is to guarantee that the indoor air maintains the quality required for safety and health, meets comfort and productivity requirements, and is as cost and energy efficient as feasible. There are six methods for reducing indoor air pollution:

1. Source removal or replacement

2. Contaminant filtration and purification

3. Indoor air dilution or ventilation with outdoor air or filtered recycled air

4. Encapsulation or other interference with a material's capacity to emit pollutants

5. A probable contaminant's time of usage

6. Building occupant education and training, particularly for operation and maintenance employees

When substantial pollution sources are present, the EPA has repeatedly declared that source management represents the most direct and predictable control approach, as well as the only effective one. When the contaminant/source is unknown, source treatment is too expensive, or the source is localised, ventilation is the preferable method of management. Medical specialists' guidance and counsel may also be sought by IAQ management as a control assistance via medical monitoring or therapy.

Effects of Indoor Air Pollution from Biomass Fuel Use on Women's Health in India

Indoor air pollution (IAP) is a major cause of sickness and death worldwide. Nevertheless, the severity is significantly greater in poor nations owing to the use of traditional biomass fuels such as wood, animal dung, and agricultural wastes for energy. Domestic cooking is done on a daily basis in rural families. Indeed, biomass smoke exposure Burning is recognised as one of the most important environmental issues confronting the world today. developing nations worldwide. It is estimated that IAP from biomass burning accounts for 4% of the total. global illness burden, and a conservative assessment suggests that the use of biomass fuel endangers the health of 400-700 million people worldwide and results in 2.8 million premature deaths per year. It mostly affects moms and children who work long hours.

inside the cooking areas. As in many other underdeveloped countries, Biomass fuel is still widely utilised in rural communities across India. In mountainous places, it is used for everyday family cooking as well as room heating.

There have been There have been several research on the consequences of biomass consumption on rural residents' respiratory health. women in India, but the total effect of biomass fuel consumption on public health, particularly that of women and children in rural India, has yet to be determined. We have included the available studies on the health consequences of IAP from the usage of biomass fuel in India and worldwide. Moreover, we have included several significant discoveries from our current research on respiratory and women's general health problems in rural West Bengal, a state in India India's eastern region. We included the results of 1260 women (median age 38 years) who have routinely cooked with biomass for the previous five years or more and have comparedThese findings were compared to those of 650 women who used liquefied petroleum gas (LPG) in a comparable area and were matched for age (median age 37 years), cigarette use, and chewing habits, as well as body mass index.

In developing nations, poverty is a key predictor of IAP from biomass fuel consumption. Individuals in these nations' rural regions are often impoverished, and their little income makes it difficult to acquire cleaner fuels like LPG. Instead, they depend on biomass, which is less expensive (or free) and more commonly accessible. No surprise, there are only a few LPG users in rural India, and most LPG owners also use biomass (mixed user) to decrease fuel costs. Apart from underdeveloped countries, impoverished people in several industrialised countries who formerly utilised cleaner fuels are now switching to biomass due to political changes and economic slump. People living in Tajikistan and Kyrgyzstan following the collapse of the erstwhile Soviet Union are two notable instances.

IAP from Biomass Burning

Biomass fuels are at the top of the fuel pyramid in terms of pollutant emissions while being at the bottom in terms of combustion efficiency (Smith et al., 1994). Particulates, carbon monoxide (CO), oxides of nitrogen and sulphur, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and trace metals such as Fe, Cu, Ni, Cr, and Pb are all found in the smoke produced by biomass burning. Airborne particles with a diameter of less than 10 m (PM10) are dangerous because they may be absorbed deep within the lungs, serving as a transport for harmful substances that normally adhere onto their surface. Biomass combustion emits higher PM10 than LPG or electricity. Particle concentrations in kitchens, for example, range from 200 to 5000 g/m3 of air when cooking with biomass fuels, compared to 200-380 g/m3 when cooking with LPG or electricity (Ellegard, 1996). Moreover, fine (aerodynamic diameter 2.5 m, PM2.5) and ultrafine particles (diameter 0.1 m) make up the majority of biomass smoke, and the majority of the mass is due to the presence of tiny particles, namely PM2.5, which is more detrimental to human health than PM10 (WHO, 1999). Biomass is thought to be significantly more dangerous than diesel because biomass smoke includes ten times the mass concentration of respirable particles with diameters of 0.5-0.8 m as diesel [12], [13].

Health Impact of Biomass Smoke Exposure: Excess Morbidity and Mortality

Prolonged exposure to biomass smoke is one of the most serious environmental and public health issues in developing nations, particularly among women who cook with these fuels and little children who attend to the flames or remain near to their moms while they cook (Smith and Mehta, 2000; Smith, 2002). Cumulative exposure to high levels of particle pollution might be dangerous for biomass users, since every 20 g/m3 rise in PM10 level in breathing air causes a 1% increase in total daily mortality (Samet et al., 2000). It is estimated that IAP from biomass use accounts for 4-5% of the global burden of disease for both deaths and disability adjusted life years (DALYs) from acute respiratory infections (ARI), chronic obstructive pulmonary disease (COPD), tuberculosis, asthma, lung cancer, ischemic heart disease, and blindness. Biomass fuel consumption has been linked to about 1.2 million to 2.8 million premature deaths worldwide.

The World Health Organization (WHO) estimates that 2.2-2.5 million people die each year (WHO, 1997). The issue is worsening with time, and the number of yearly premature deaths attributable to IAP from biomass fuel consumption is expected to reach 9.8 million by 2030. Every year, IAP from biomass burning leads to 4-6% of the national illness burden and 400,000-550,000 premature deaths in India.

Scope of the Work and Objective of the Study

Several PAHs and VOCs found in biomass smoke, such as benzo(a)pyrene [B(a)P] and benzene, are carcinogenic in humans (Zhang and Smith, 1996). According to Smith and Liu (1994), women in India who cook with biomass were exposed to a B(a)P comparable to smoking 2-20 packs of cigarettes per day on average. It is fair to infer that women in impoverished nations who are persistently exposed to air polluted with chemicals produced by biomass burning face a significant health risk. However, the level of IAP from biomass fuel use in rural households in India, its effects on the respiratory and systemic health of women who cook with these fuels, and the possible mechanisms of such effects at the cellular and subcellular levels are largely unknown because clinicians, scientists, and administrators have paid little attention to this important public health issue. In light of this, the current study sought to assess the health effect of IAP from biomass fuel usage among rural women in India who cooked with these fuels.

Reduction in Lung Function

Biomass users had considerably lower FVC, FEV1, PEFR, and FEF25—75% FVC than LPG users, indicating a considerable loss in lung function. Overall, pp) unit root was worse in 70.3% of biomass users compared to 34.7% of LPG users. The restrictive form of impairment predominated (FVC 80% expected). Decreased pp) unit root was more common (75%) in women who did not have separate kitchens than in those who did (62%, p 0.05).

Like the present finding, reduction in lung function has been observed in women who are chronically exposed to biomass smoke. As in Eastern India, the most common kind of lung function impairment among biomass users was a restrictive type of ventilatory defect, with FVC 80% of the anticipated FVC. The decrease in FVC might be related to decreased inspiratory effort, which reduces total lung capacity, or to subclinical edoema.

and alterations in airway closure or an increase in pulmonary blood volume (Mason et al., 2000). Lung fibrosis caused by illnesses such as pulmonary TB might result in a restricted spirometry pattern. Moreover, the presence of CO, PM10, and PM2.5 in biomass smoke may cause lung tissue damage due to their propensity to produce free radicals in the bronchial mucosa and alveoli. High-resolution computed tomography of the thorax of Turkish women who cooked with biomass showed a number of anatomical alterations, including thickening of interlobular septa. The most likely mechanism of FVC decrease is because active neutrophils are capable of producing collagenase, elastase, neutral protease, and different oxidants, all of which significantly derange the alveolar structure. Eventually, type I alveolar cells and capillary endothelial cells are lost, while type II cells and interstitial fibroblasts proliferate and type I collagen accumulates, potentially leading to fibrosis. As a result, the alveolar wall loses flexibility, and the lung's essential capacity is significantly diminished. As a result, among biomass fuel users, lung inflammation with accompanying restrictive lung function impairment may imply an increased risk of interstitial lung fibrosis, sarcoidosis, or adult respiratory distress syndrome (RDS). Children living in houses that utilised biomass fuel had worse lung function, as measured by lower FVC and FEV1.

Adverse Cellular Lung Reaction

Every day, around 10,000-15,000 L of air is used, which includes both life-sustaining oxygen and a variety of hazardous gases, compounds, and bioaerosols. As a result, the lungs and airways have a powerful cellular defence system to protect the gas exchange region from inhaled hazardous chemicals. The alveolar macrophages are the most significant defence cells in the lungs (AMs). They easily swallow airborne particles and germs, ensuring the lung epithelium's sterility and cleanliness for successful gas exchange. The total surface area of inhaled carbon inside an AM is predicted to be 13 times more in women who cook with biomass fuels compared in nonusers, and 7.5 times greater in children from biomass-using families. Tudy may be caused by neutrophilic and eosinophilic airway irritation. Also, the number of multinucleated AMs rose considerably among biomass consumers, indicating changed AM activity. Biomass users had a higher prevalence of ciliocytophthoria, or injury to the ciliated epithelial cells of the airways, which is a common feature of respiratory virus infections; goblet cell hyperplasia and excess mucous production, presumably to facilitate disposal of excess inhaled pollutants; Curschmann's spiral, implying underlying airway obstruction; Charcot-Leyden crystal, implying eosinophilia and accompanying.

Fine and ultrafine particles included in biomass smoke may cause the generation and release of proinflammatory mediators (cytokines, chemokines, etc.) from AMs, stimulating the migration of inflammatory cells from circulation to the lungs. In addition, indoor particles are more bioactive on AMs than outside particulates. Moreover, these inflammatory mediators may be produced by organs other than the lungs, since lung inflammation has been shown to be mediated by tumour necrosis factor-alpha synthesis in the liver. Smoke absorption has been studied. Increased circulating leukocyte-platelet aggregates represent an additional prothrombotic mechanism, as well as a risk factor for thrombosis, because they promote the formation of fibrin via induction of tissue factor expression on t cells, release of superoxide anions, and production of inflammatory cells from polymorph nuclear leukocytes (PMN), which, in turn, augments the formation of fibrin. Taken together, the data point to a higher risk of CVD among biomass users.

compared to 16.2% of LPG users, was changed in 29.7% of women who cook with biomass. In comparison to 10.1% of LPG users, around 22% of biomass users reported oligomenorrhea, or extended cycles (36 days). Nevertheless, we found no difference in the incidence of short cycles among biomass and LPG users. Extended cycles may be harmful to women's reproductive health since women with oligomenorrhea are more likely to have abortions, stillbirths, and premature birth. Moreover, we discovered a higher rate of spontaneous abortion and stillbirth among biomass users.

A high percentage of biomass consumers had extended cycles, which we discovered. It is unclear if the move towards longer cycles among biomass users is attributable to the extension of a particular phase of the menstrual cycle or to missing periods and reporting extended cycles. The endocrine system regulates the menstrual cycle, and various variables may impact its duration and regularity. The ovary, the estrous cycle, or reproductive hormones like as oestrogen, follicle stimulating hormone (FSH), and leuteinizing hormones may be affected by biomass.

The rous cycle may result in longer cycles. Many biomass users' long menstrual cycles may be due to anovulation and relatively low oestrogen exposure. In line with this, we discovered a decrease in plasma oestrogen and progesterone levels among biomass users. Also, the concentration of LH was increased while the amount of FSH remained essentially unchanged. Changes in plasma LH levels during the follicular and luteal phases have been seen in female traffic officers who have been persistently exposed to vehicle pollution. Similarly, smoking and ETS have an antiestrogen impact on female reproductive hormones. Consequently, chronic exposure to biomass smoke has been demonstrated to affect female reproductive hormone levels. Biomass users are often poorer than LPG users, and women in these households have the added stress of fuel collection (wood and agricultural leftovers) and processing (dung cake). As a result, physical tiredness and stress caused by poverty are far more prevalent among these women. Each of these characteristics may be significant predictors of longer menstrual cycle duration. Likewise, we discovered a significant increase in cortisol levels among biomass users, indicating a higher degree of stress in these women.

Chromosomal Breakage

B(a) P, 1,2 butadiene, and benzene are among the mutagens and probable carcinogens found in biomass smoke. As a consequence, persistent exposure to biomass smoke may cause genetic damage. We investigated this hypothesis by doing the MN test and the Immunoblotting, which are chromosomal and DNA damage indicators, respectively. We identified three times more MNs in exfoliated buccal and airway epithelial cells from biomass users than from LPG users reflecting a higher incidence of chromosomal disruption in cells.

Depression and Other Neurobehavioral Changes

Long-term exposure to high levels of air pollution may result in brain damage. We looked at this in biomass users by assessing the incidence of neurobehavioral disorders. In comparison to LPG users, biomass users typically complained of weariness and foot numbness. Also, they experienced a higher incidence of worry, sadness, aberrant smell, taste, and eyesight, as well as momentary memory loss. The symptoms were mostly psychoneurological or caused by aberrant responses of the cranial nerves (abnormal smell, taste, and vision), peripheral nerves (foot numbness), and mucous membrane irritations (cough, shortness of breath, and eye and nose irritations). Multivariate logistic regression analysis revealed a substantial positive connection between PM10 and PM2.5 levels in indoor air, especially the latter, and depression (OR = 1.26 and 1.33; 95% CI and; 1.10-1.55 and 1.16-1.72 for PM10 and PM2.5, respectively). Similarly, PM10 and PM2.5 levels were linked to transitory memory loss, burning sensations in the extremities, a diminished sense of smell, and impaired eyesight. Lifetime exposure to biomass smoke, estimated as exposure hour-years, linked strongly with depression (r = 0.535, p 0.001) and other symptoms.

Since they are inexpensive and frequently accessible, biomass fuels are widely employed in rural India for home cooking and room heating. When biomass is used in traditional ovens in poorly ventilated kitchens, as is prevalent in rural India, it releases particles and gaseous pollutants that cause three times the interior pollution of LPG-using homes. Women who cook with these fuels on a daily basis suffer from a slew of physical and mental health issues. Lung function reduction, asthma, COPD, airway inflammation, covert pulmonary haemorrhage, platelet hyperactivity and associated higher cardiovascular risk, immune alteration, reproductive failures, underweight baby and hormonal imbalance, chromosomal and DNA damage, airway cell metaplasia and dysplasia and consequent higher risk of cancer in the airways and lungs, and depression with changes at the neurotransmitter level are examples. Even after correcting for possible confounders such as socioeconomic status and ambient cigarette smoke, the changes in indoor air remained positively linked with PM10 as well as PM2.5 levels. Since biomass is the primary source of home energy in poor countries across the world, the health impairments reported in this research may reflect the health problems of women in other developing countries as well.

As a result, the magnitude of the problem appears enormous, necessitating the immediate attention of all parties concerned to this public health issue. Long-term solutions might include the use of alternative energy sources such as solar power and/or the distribution of cleaner fuels such as LPG to rural communities at a low cost. As an urgent remedy, we advocate launching a campaign to install user-friendly smokeless ovens and improve kitchen ventilation in all of the country's biomass-using families.

Health Effects of Urban Air Pollution in India

Sources of Air Pollution in Urban India

In Indian cities, there are three major sources of ambient air pollution: (i) emissions from motor vehicles caused by the combustion and evaporation of automotive fuels, (ii) emissions from industrial units and the construction of buildings and infrastructure in and around cities, and (iii) emissions from internal sources. The contribution of automotive sources is rising over time. Delhi has the most vehicles in the nation, more than three other metros combined (Mumbai, Kolkata, and Chennai). The population of Delhi has expanded from 3.53 million in 1970 to 13.80 million in 2001, a 3.9-fold increase in 30 years. In contrast, the number of registered motor cars in the city in 2001 was 3.42 million, up from 0.2 million in 1970-1971, a 17-fold increase that considerably outpaced population growth. Similarly, the total number of registered automobiles in Bengal in January 2000 was 721,775, about three times the figure in 1982-1983. This significant increase in vehicle numbers is mirrored in the urban air pollution situation.

Poor Fuel Quality and Adulteration

Internal combustion engines in automobiles burn a combination of air and fuel to create energy that moves the vehicle. Many variables determine the kind and number of pollutants emitted during this combustion. One of them is the kind of fuel—petrol, diesel, or compressed natural gas (CNG). Despite the fact that petrol and diesel are more harmful than CNG or LPG, they are widely utilised in India. Yet, the advantage of utilising cleaner automobile fuel has been shown beyond question in Delhi, where the level of ambient pollution has significantly decreased since the introduction of CNG as a fuel for public transportation vehicles. The quality of fuel and lubricating oil has also contributed greatly to India's transport air pollution. Indian transportation fuels continue to lag behind those now accessible in Europe and the United States (CSE, 2002). Indian gasolines are very volatile, and the great majority of gasoline cars are carbureted rather than fuel injected. These factors, together with India's high ambient temperatures, raise the possibility of evaporating hydrocarbons producing ground-level ozone. Benzene was not previously restricted in Indian petrol. As a result, ambient benzene levels in Delhi in the late 1990s were many orders of magnitude higher than the European Union's maximum allowed limit (CSE, 2002). Another critical aspect is gasoline and lubricating oil adulteration. This is especially prevalent when the operators do not own the cars.

Nuclei Mode or Ultrafine Particles

Particles in this category are less than 0.1 m in size. They are sometimes referred to as ultrafine particles (UFPs). They do not linger in the air for long because they deposit or swiftly form small particles by coagulation. UFPs may be found in high concentrations in polluted urban air (Jaques and Kim, 2000). They contain a carbonaceous core with inorganic and organic components attached that may be harmful to one's health. UFPs have less mass than coarse particle fractions but a substantially higher number and a relatively large surface area-to-mass ratio, making them possible carriers of hazardous gaseous chemicals. UFPs are immune to alveolar macrophages (AM) surveillance in the lungs, which is normally quite effective for bigger particles (Hahn et al., 1977). High-dose UFP exposure may result in severe pulmonary inflammation and bleeding, severe alveolar and interstitial edoema, destruction of epithelial and endothelial cell layers, and mortality (Oberdorster et al., 1992; Peters et al., 1997; Oberdorster, 2000). Very low levels of UFP exposure from vehicle exhaust may cause cardiovascular issues, lung illnesses, and cancer**.**

SO_2 and NOx

Coal combustion is a significant producer of sulphur dioxide (SO2) in the atmosphere. It's an acidic gas that reacts with water vapour in the atmosphere to form acid rain. SO2 in the environment may harm human health (Routledge et al., 2006), notably in those with asthma and chronic lung disorders, and it aggravates respiratory symptoms and impairs breathing in sensitive people (Lipfert, 1994). Nitrogen oxides (NOx) are produced during high-temperature combustion processes by the oxidation of nitrogen in air or fuel. Nitric oxide (NO) and nitrogen dioxide are the two most common nitrogen oxides (NO2). The largest source of NO is road traffic, which emits NO from both gasoline and diesel engines. NOx is a precursor to the formation of ozone in the troposphere. Nitrogen oxides are immunotoxic and increase the risk of respiratory tract illness. Prolonged or frequent exposure to high NOx concentrations in breathing air may induce lung irritation and, as a result, severe respiratory disease.

Carbon Monoxide

CO is a poisonous gas that is released into the environment as a byproduct of combustion and the oxidation of lipids and other organic molecules. CO is nearly totally created by vehicle traffic and lingers in the atmosphere for about one month before being oxidised to CO2. Petrol-powered cars are the major sources of CO, strongly binds to haemoglobin in red blood cells, resulting in the formation of carboxyhemoglobin. This hinders oxygen transmission throughout the blood and may have a negative impact on tissues with high oxygen requirements, such as the cardiovascular and neurological systems. Recent research found that prolonged CO exposure may result in unfavourable birth outcomes such as low birth weight and intrauterine development retardation.

Air Toxics of Biological Origin

Biological substances found in dirty air may induce a variety of ailments. These contaminants come from a variety of sources. People and animals spread viruses; germs are transported by man, animal, soil, and plant detritus; and domestic pets are sources of saliva and animal dander. The protein in rat and mouse urine is a strong allergen. As it dries, it has the potential to become airborne. Airborne microorganisms, in addition to particle pollution, enter the body during breathing. Some of these are harmful to humans. Mycobacterium tuberculosis, for example, causes TB, while Streptococcus pneumoniae causes bacterial pneumonia. Every year, pneumonia kills 2 million children worldwide (20% of all child mortality), with Africa and Southeast Asia accounting for 70% of these deaths. Virus infections, like bacteria, have been related to air pollution. Some of the viruses that spread through polluted air are Mumps virus (mumps), Myxovirus influenza (influenza), Poliovirus (poliomyelitis), Rhinovirus (common cold), Rubella virus (measles), Varicella virus (chicken pox), Variola pox virus (small pox), Haemophilus influenzae, respiratory syncytial virus (RSV), influenza, parainfluenza, and adenoviruses.

Due to poor housing conditions, older home age, relative lack of sun exposure, and lack of insulation, the presence of fungus in the indoor environment increases the risk of respiratory disorders such as mouth toxicosis and airway allergies. The difficulties might worsen and need hospitalisation (Khalili et al., 2005). Pollens and other allergens in the air are primary causes of bronchial hypersensitivity and asthma. The most prevalent reason for hospitalisation in children is asthma exacerbation. In allergic asthmatics, airborne bacterial and viral infections increase the chance of hospitalisation (Murray et al., 2006). Pollen allergy and eosinophil buildup in the nasal passages and airways are often related with pollen exposure.

Health effects of air pollution

The negative consequences of air pollution on human health have been known for ages. 1.1 billion people worldwide breathe filthy, toxic air (UNEP, 2002). Since epidemiological studies have proven a clear association between air pollution and health concerns ranging from morbidity (sickness) to mortality, the consequences may be severe (death from illness). It should be noted that around 8000 people die every day from illnesses caused by air pollution exposure throughout the world. In This health burden is not evenly spread, with nearly two-thirds occurring in developing nations as a result of high levels of outdoor air pollution in many Asian cities. For example, each year, 500,000 people die in China as a result of air pollution, compared to 60,000 in the U.s.

Excess Mortality

The 1952 London fog event decisively proved a link between air pollution and higher mortality (Logan, 1952). Several epidemiological studies conducted in the United States and Europe since then have established a clear relationship between air pollution exposure and excess mortality. Air pollution is linked to an increased risk of acute respiratory infections, which are the leading cause of newborn and child death in poor nations. Each 10 mg/m3 increase in yearly average PM2.5 level may raise the risk of all-cause, cardiopulmonary, and lung cancer mortality by 4%, 6%, and 8%, respectively (Pope et al., 2002). A 10 mg/m3 rise in PM10 has been linked to 0.76% more deaths from cardiovascular causes and 0.58% more deaths from respiratory disorders (Analitis et al., 2006). Dockery and colleagues (1993) discovered a link between PM10 levels and death rates from both lung cancer and cardiopulmonary disorders.

CHAPTER - 7

CONCEPT OF MORBIDITY

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Apart from death, air pollution has the potential to cause or worsen a variety of ailments. Excess morbidity is often shown in absence from school and work, reduced activity at home, increased attendance at outpatient medical services, and emergency clinic visits and hospitalization Acute bronchitis, pneumonia, emphysema, bronchiectasis, chronic airway blockage, and other air pollution-related lung illnesses that frequently need hospitalization.

Additive and Synergistic Effects of Airborne Pollutants

Upon inhalation, air contaminants act collectively rather than individually on the target tissues. Pollutants may also react with one another, and some of the chemicals produced may be more harmful than the underlying pollutants. The additive or cumulative reaction to a combination is the total of the effects caused by the mixture's constituent components. In theory, the cumulative effect occurs only when each pollutant's impact is independent. Potentiation occurs when a pollutant does not elicit a reaction when operating alone but boosts the impact of another co-occurring pollutant. Synergism refers to any combination of acts that produces a greater outcome than if the actions were completely independent of one another. In other words, the total is larger than the sum of its parts in a synergistic process. For example, smoking combined with exposure to automobile emissions or air pollution increases the risk of lung cancer far more than either smoking or asbestos exposure alone.

Toxicologists and epidemiologists have a problem in assessing human exposure to complex combinations of air pollutants due to the large range of variances and confounding variables that make exposure assessment, research design, and data interpretation challenging. As a result, it is unclear whether the observed alterations in human subjects may be attributable only to benzene. To investigate these issues, concurrent tests with experimental animals under controlled laboratory circumstances are required, in which the animals are exposed to calibrated quantities of benzene in drinking water as well as by breathing. Comparing the health responses to controlled benzene exposure with those acquired from a population exposed to automotive emissions may provide insight into the potential health impacts of benzene from vehicular emissions.

Materials and methods

Between 2000 and 2006, we performed epidemiological research on the health effects of the study included 6862 nonsmokers from Kolkata (formerly Calcutta). capital of West Bengal in Eastern India) and Delhi, which has a median age of of 43 years and 3715 age- and sex-matched nonsmokers as controls from relatively low-income countries. West Bengal rural regions with lower levels of particle pollution (PM10) Much lower. Moreover, 12,688 school-age youngsters (ages 8 to 17) of These two cities, as well as 5649 people from rural West Bengal, were investigated. The Chittaranjan National Cancer Institute's Ethics Committee accepted the research procedure.

Kolkata is a city in India. Statistics on the concentration of particulate matter with an aerodynamic diameter of less than The Central Pollution Control Board got 10 m (PM10) in ambient air.Delhi and Kolkata's West Bengal State Pollution Control Board. The occurrence of A validated questionnaire survey was used to quantify respiratory symptoms. organised questionnaire. The American Thoracic Society's pulmonary function test (PFT) protocol was followed (ATS, 1995). The Global Initiative criteria were used to diagnose chronic obstructive pulmonary disease (COPD). for COPD (Chronic Obstructive Pulmonary Disease) (GOLD; Pauwels et al., 2001). Lung cellular

The cytology of exfoliated airways was examined to assess the response to air pollution. Sputum stained with Papanicolaou. Hematological parameters such as total and differential counts of white blood cells (WBC) and total platelet count were measured utilising a hemocytometer on freshly obtained venous blood without anticoagulants under a light microscope. P-selectin (CD 62P) expression on platelet surface, b2 Mac-1 integrin (CD11b/CD18) expression on circulating neutrophils and monocytes. Platelet activation was measured, and circulating leukocyte-platelet aggregates were found. Flow cytometry was used to determine this. The micronucleus (MN) test was used to look for chromosomal breakage, while single cell gel electrophoresis was used to look for DNA damage (Comet assay) Superoxide dismutase (SOD), an antioxidant enzyme, was tested in plasma.

Effects on Respiratory Health

Since most airborne contaminants enter the body through breathing, the lungs and airways are the major target organs. The trachea (windpipe) represents the lungs' airways, and beyond it are bronchi (with cartilage cover) and bronchus (without cartilage). The bronchioles connect to alveoli, which are air pockets with an average diameter of 200 mm. According to recent research, there are roughly 480 million alveoli in both lobes of an adult human lung, with males having more alveoli and a bigger lung capacity than women (Ochs et al., 2004). A single alveolus has an average size of 4.2 106 m3. Alveoli account for around 64% of lung space (Ochs et al., 2004). The surface area of the human lungs is 1400 m2, and we inhale around 15 m3 of air each day (that is, 15,000 liters).

The weight of this breathed air is more than the weight of the food and water we consume in a day. During repose, healthy people' lung volumes and breathing frequency are 400-500 mL and 15-17 breaths per minute, respectively According to recent research, the number of respiratory units remains constant from infancy to maturity, however the tiniest bronchioles and alveoli grow in size to create the increased lung capacity with age and height. We discovered that 32.1% of children in Delhi had one or more respiratory symptoms, compared to 18.2% of age- and sex-matched children in rural regions (Lahiri et al., 2006b). URS and LRS were found in 23% and 17% of youngsters in Delhi, respectively, compared to 14.6% and 8% in their rural counterparts (p 0.05). Girls were more likely than males to have respiratory symptoms (36.3% vs 30%).

After adjusting for possible confounders such as parental smoking and socioeconomic status (SES), multivariate logistic regression analysis demonstrated a positive relationship between ambient PM10 levels and the occurrence of respiratory symptoms. A comparable research of adults found that 33.2% of Delhi residents (n = 6005) had one or more respiratory symptoms in the previous 3 months, compared to 19.6% of age- and sex-matched participants (n = 1046) in rural West Bengal, showing 1.7 times larger prevalence in urban respondents (Lahiri and Ray, 2006a). URS was found in 21.5% of Delhi dwellers compared to 14.7% of rural individuals. Sore throat (8.1% vs. 4.5% in rural regions), runny or stuffy nose (7.8% vs. 5%), and common cold with fever (7.4% vs. 4.1%). We discovered LRS in 22.3% of Delhi residents and 12.7% of rural individuals.

Rise in Bronchial Asthma

Asthma is caused by intermittent constriction of the airways and accompanying shortness of breath. Early symptoms include wheezing, chest constriction, shortness of breath, and a persistent dry cough. We discovered current asthma (dyspnea and wheeze at any point in the last 12 months) in 4.6% of Delhi students compared to 2.5% of age- and sex-matched rural children. Asthma was identified by a doctor in 1.7% of Delhi children and 0.9% of rural children. Asthma was more common in big families (>6 members), and multivariate logistic regression analysis demonstrated a link between particle air pollution (PM10 level) and asthma episodes (OR = 1.28, 95% CI, 1.07-1.42) but not asthma prevalence. Current asthma and physician-diagnosed asthma were prevalent in 7.6% and 3.6% of Delhi residents, respectively, compared to 3.9% and 2.1% in rural individuals. In Kolkata, 5.8% of people had physician-diagnosed asthma, compared to 3.5% among rural subjects. Notwithstanding the fact that asthma has a hereditary propensity, exposure to air pollution aggravates asthma episodes. Strong relationships have been documented between severe asthma signs and cumulative exposures to exhaust from diesel-fueled engines, as well as occupational exposures to benzene scarring on lung tissue, resulting in lung elasticity loss, such as in the If you have pneumonia or TB, you should see your doctor. Obesity and neuromuscular issues are other possibilities.

This may result in a reduction in restrictive lung function. On the other hand, obstructive lung disease A reduction in the forced expiratory volume in one indicates a function impairment. Second, the (FEV1)/FVC ratio is less than 70%. FEV1/FVC decline is mainly caused by Large airway blockage when falling in Forced expiratory flow between 25% and75% FVC, mid expiratory force (FEF25-75%) indicates a slight airway blockage. Dassen and colleagues (1986); Vedal et al. (1987). Obstructive lung function is prevalent in patients.

6Asthma and chronic bronchitis are also present. Many investigations have shown a FVC and FEV1 decrease when particle air pollution concentrations rise. We discovered a decrease in lung function in 43.5% of Delhi pupils. compared to 25.7% of matched controls from West Bengal's rural districts and Uttaranchal. The prevalence of restrictive (20.3% against 14.3% in rural) and obstructive (13.6% versus 8%) asthma among Delhi children was higher. as well as a combination of restrictive and obstructive lung function impairments). Apart from a higher prevalence, the extent of pulmonary function impairments was substantially greater.

There is more in Delhi. For example, 7.3% of the city's pupils had serious lung disease. function deficiencies, compared to 2.2% of children from rural regions. The number of pollutants in the air was much lower. Similarly, to children, 40.3% of Adults in Delhi exhibited lower lung function compared to 20.1% of rural participants. Their FVC, FEV1, FEF25-75%, and peak expiratory flow rate (PEFR) data were averaged.

declined by 9.4 percent, 13.3 percent, 10.4 percent, and 9.3 percent, respectively. Type restriction Lung function impairments were more common (22.5%) than obstructive type (in 10.7%), and 7.1% of Delhi residents had both types of lung function impairments. The degree of the loss in lung function was likewise substantially greater in Delhi. For example, 6.7% of Delhi people have significant lung limitation (FVC). 40% against 1.3% of rural participants (p 0.001) and 2.7% of Delhi residentscompared to 0.8% of their rural counterparts (p 0.001), had significant lung obstruction (FEV1/FVC 30%). We discovered that 46.9% of Kolkata residents have lowered their consumption.

The amount of pollutants in the air was much lower. Comparable changes were reported among Delhi students and adults. The AM number correlated closely with the PM10 level, with the AM number being greatest in winter, lowest in monsoon, and intermediate in summer. AMs were also shown to have a direct association with the level of exposure to urban air pollution. Occupationally exposed to high levels of vehicle pollution, such as traffic cops, drivers, garage workers, and street hawkers in Kolkata and Delhi, had considerably higher AM counts than less-exposed office workers (Basu et al., 2001; Lahiri et al., 2006b). As a result, the AM number in sputum seems to be a sensitive biomarker of exposure to air pollution. Despite the increase in cell number, air pollution exposure may decrease AM function because particle overloading affects AM phagocytic activity, especially after infection, which causes an increase in interferon g production. Moreover, UFPs in urban dust and diesel exhaust produce cytoskeletal toxicity, impairing macrophage activity and reducing lung defence.

Upregulation of Elastase Activity

Elastin is a fibrous protein found in the lungs' elastic tissues. Elastase, a proteolytic enzyme found in neutrophil and AM lysosomes, may degrade elastin. Excess elastase released by these cells promotes the development of emphysema by degrading the alveolar wall. Through cytochemical research, we discovered that this enzyme was overexpressed in the AMs and neutrophils of Kolkata and Delhi people. Elastase-positive AMs were 9.4 1.9/hpf in Delhi dwellers compared to 2.9 0.8/hpf in rural controls. Residents of Kolkata exhibited 58% elastasepositive AMs, with approximately 52% showing strong enzyme activity. In comparison, only 34.9% of AMs tested positive for this enzyme, with 16% demonstrating strong elastase activity among rural populations. In controls, enzyme activity was restricted to the cell, but in urban persons, a significant quantity of the enzyme was released into the extracellular matrix. Since the enzyme is only active when released from the cell of origin, the urban group is likely to have more tissue breakdown. The largest number of elastase-containing AMs were detected among automotive service station employees among all people studied in Kolkata.

Cardiovascular Changes

Air pollution and CVDs are inextricably linked. Angina, cardiac insufficiency, hypertension, and myocardial infarction (MI), or heart attack, are all linked to air pollution. In 1997, respiratory disorders (COPD, pneumonia, influenza, etc.) accounted for just 8.5% of all air pollution-related fatalities in the United States, whereas cardiovascular diseases accounted for 39.5% of all deaths (Greenle et al., 2000). As a result, CVDs, rather than respiratory diseases, are the leading causes of mortality from air pollution exposure. As compared to Europe and the United States, urban Indians have a lower risk of CVDs and die from these illnesses at a younger age [14], [15].

Air Pollution and Other Risk Factors for Hypertension

Spearman's rank correlation test revealed a substantial positive relationship between PM10 levels in Delhi's air and people' SBP and DBP. DBP had a greater connection (r = 0.350, p 0.005). High SES, higher RSPM level, and overweight/obesity were shown to be risk factors for hypertension in a conditional logistic regression study. Spearman's correlation revealed a strong positive association between BMI and systolic (r = 0.297, p 0.01) and diastolic hypertension (r = 0.327, p 0.005) hypertension. Hence, particle air pollution combined with lifestyle and SES substantially contributed to the increased incidence of hypertension in Delhi. Studies dating back to the late 1990s, like this one, have consistently found a link between PM10 levels and hospital admissions for CVDs (Schwartz, 1999; Burnett et al., 2001; Moolgavkar, 2000; Lin and Kou, 2000) and sudden deaths in patients with stable angina and MI (Lind et al., 2001; Peters et al., 2001, 2004). Each 10 mg/m3 rise in PM2.5 was shown to be related with a 2.1% increase in overall mortality from ischemic heart conditions in combined analysis across six eastern U.S. cities (Schwartz et al., 1996). Those with preexisting CVDs and the elderly are at the greatest risk. Moreover, those with diabetes are twice as likely to have CVDs caused by airborne pollution.

Mechanism of Cardiovascular Effects of Air Pollution: Upregulation of Platelet Activity

The process by which air pollution affects the cardiovascular system is still poorly understood. Seaton et al. (1999) proposed that pollutant exposure causes a transient increase in blood coagulability, which was later confirmed by Schwartz (2002), who found a link between PM10 and all three markers of cardiovascular risk: a higher level of fibrinogen in blood plasma, a higher number of platelets in circulation, and an elevated WBC count. Several other workers have linked air pollution, especially the PM10 level, with the markers of adverse cardiovascular events such as increase in peripheral white cell counts (Salvi et al., 1999), elevation of interleukin-6 point, upregulation of C-reactive protein, rise in plasma viscosity due to increase in fibrinogen level, In our flow cytometric investigation, inhabitants of Delhi had 3.4 0.6% P-selectin-expressing activated platelets in circulation, compared to 1.6 0.4% in age- and sex-matched rural patients (p 0.001). Additionally, the absolute number of P-selectin expressed platelets in circulation was 10,268 ± 1232 (mean ± SE) per mL of blood in urban participants against 3682 ± 960/mL in rural controls, showing 2.8 times more activated platelets in circulation of the former group.

Neurotoxicity of Air Pollution

While harmful effects of PMs on the peripheral nervous system and the central nervous system (CNS) have been observed, air pollution exposure may damage mental health in addition to physical health (Kilburn, 2000). We discovered depression in 69% of Delhi residents compared to 35.4% of rural controls (Lahiri et al., 2006b). Besides, the residents of Delhi had higher prevalence of several other neurobehavioral symptoms such as burning sensation in extremities (7% versus 3% in control), anxiety (17.8% versus 6.6%), feeling of drunkenness (5.6% versus 3%), inability to concentrate (23.2% versus 9.2%), transient loss of memory (21.6% versus 9.2%), reduced sense of smell (3.4% versus 0.7%), blurred vision (4.9% versus 2.2%), and sleep disturbance (7% versus 3%). The increased incidence of these symptoms was followed by an increase in plasma epinephrine (E) and norepinephrine (NE) levels, as well as a decrease in plasma dopamine (DA), indicating changes in plasma catecholamine levels.

Additionally, plasma acetyl cholinesterase (ACHE) concentration was lowered by 43% in the inhabitants of Delhi ($p < 0.001$), indicating alterations in cholinergic neurotransmission. Adjusting for age and passive smoking as potential confounders, logistic regression analysis demonstrated positive correlation between the PM10 level and the concentration of E (OR = 1.33; 95% CI, 1.08-1.67) and NE in plasma (OR = 1.47; 95% CI, 1.10-2.12). Similarly, a positive relationship was identified between plasma E (OR = 1.23; 95% CI, 1.05-1.52) and NE (OR = 1.34; 95% CI, 1.12-1.71). Hence, the alterations in catecholamines might be ascribed, at least in part, to continuous inhalation of contaminated air with regard to particles and benzene (Lahiri and Ray, 2006a). 6Changes in the CNS, like the current results, have been associated to vehicle emissions (Kilburn, 2000). Benzene contained in polluted air generated distinct alterations in NE and DA turnover in some regions of the hypothalamus.

Depletion of SOD and Total Antioxidant Status

As compared to rural controls, Delhi inhabitants had a substantial reduction (p 0.05) of erythrocyte SOD. (Lahiri and Ray, 2006a). SOD levels were reduced by 23% in men and 52% in women. Overall, a 30% decrease in SOD content in blood was reported among Delhi nonsmokers, signifying a considerable deficiency in antioxidant activity, particularly among the city's women. The typical range for total antioxidant levels in blood is 1.3-1.77 mmol/L of plasma. This study's control male individuals had a greater value than the usual limit, while the females had such a lower value. The total antioxidant level in the control group was normal. In contrast, the population of Delhi had a dramatically lower amount of total antioxidant. The urban mean was one-fourth that of the control mean, and it was 65% lower than the lowest limit of normal range**.**

While a negative association (r values -0.257 and -0.470, respectively, p 0.05) was identified between the Respirable level and SOD and total antioxidant status, particulate air pollution might be a significant contributing factor to reduced SOD and total antioxidant capacity. In line with our results, PM2.5 has been found in laboratory animals to drastically increase lipid peroxidation levels while decreasing SOD, catalase, and antioxidant enzyme activities. A reduction in SOD level in the liver has been recorded after benzene toxicity (Pan et al., 2003). Holovska et al. (2005) discovered a reduction in glutathione peroxidase (GSHPx) and glutathione-S-transferase (GST) activity, but not in SOD or thiobarbituric acid reactive substances (TBARS), in the liver of rats following benzene exposure in recent research**.**

Micronucleus Formation and Other Nuclear Anomalies

Microscopically visible, round or oval chromatin aggregates in the cytoplasm adjacent to the nucleus are referred to be MN (Schmid, 1975). An MN comprises of a fragment of the chromosome or chromatid or a full chromosome that has not been included in the spindle machinery owing to abnormal mitosis (Schmid, 1975). Evaluation of the quantity of MNs is extensively used to assess the genotoxic damages and its creation is regarded to be a simple biomarker of mutagenic effects of environmental pollutants (Stich et al., 1982). When air contaminants enter the bloodstream via the nasaloropharyngeal pathway, the buccal mucosa's epithelial cells are constantly in touch with foreign particles. A comparison of MN count between rural and urban persons without tobacco smoking and chewing behaviours indicated 2.3 times higher value in the latter group (3.5 vs 1.5 micronucleated cells/1000 cells, $p < 0.001$). Since MN development is connected with chromosomal breakage, a greater incidence of chromosomal damage in buccal and airway epithelial cells, which are in close contact with inhaled pollutants, may be expected among Kolkata and Delhi residents. Alongside MNs, Comet assay indicated DNA damage in 33.8% lymphocytes of the people of Delhi and Kolkata compared with 18.5% in controls

Air Pollution and Cancer

Cancer is becoming more common among the people living in Indian cities. The fact that Kolkata has the highest age-adjusted risk of lung cancer per 100,000 population compared with all the other cities analysed is very significant (ICMR, 2004). Since a huge number of carcinogens are found in automotive exhausts as well as industrial and residential emissions, air pollution is thought to be a significant factor to the illness. Benzene and benzo(a)pyrene are two well-known environmental carcinogens. Benzene is a Class 1 carcinogen (proven as a human carcinogen) but benzo(a)pyrene and diesel exhaust particles belong to Class 2A (possibly harmful to humans) according to the International Agency for Cancer Research. (IARC, 1982). Diesel exhaust exposure has been linked to an increase in lung cancer incidence, whereas reactive benzene metabolites, particularly p-benzoquinone, cause acute myeloid leukaemia, chronic lymphocytic leukaemia, aplastic anaemia, and myelodysplastic syndromes.’

CHAPTER - 8

AIR POLLUTANTS EXPOSURE AND HEALTH EFFECTS DURING THE MILAGRO–MCMA2006 CAMPAIGN

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According to the 2000 census, the Mexico City Metropolitan Area (MCMA) is one of the world's most densely inhabited cities, with 18 million residents (INEGI, 2001). MCMA is located at an elevation of 2240 metres above sea level and is bordered by mountains to the south, west, and east. Local emissions may cause air pollution to impact wide regions inside constricted valleys, were limited air flow concentrates contaminants. MCMA gets significant sun radiation due to its altitude and latitude, a situation that, when combined with a less efficient combustion, increases the photochemical generation of secondary pollutants such as ozone and particulate matter (PM) (Molina and Molina, 2002).

Several of the qualifying air pollutants have decreased in concentrations in Mexico City during the previous decade. Nonetheless, ozone and PM concentrations in specific metropolitan zones stay over the Mexican level for several days. In 2006, 40% of ozone (O_3) readings above the 0.11 ppm 1-hour limit, while 50% exceeded the 0.08 ppm 8-hour standard. PM smaller than 10 m (PM10) concentrations were over the 120 g/m3 24-hour guideline 20% of the time, and more than 4 million children lived in locations where PM2.5 concentrations were above the 15 g/m3 yearly threshold (SMA, 2007). Additionally, several compounds released by mobile sources, such as benzene, 1,3-butadiene, formaldehyde, cadmium, and others, are known to be carcinogenic or genotoxic (IARC, 2009); they are not frequently monitored, but have significant quantities both outside and inside. According to findings from the extensive MCMA-2003 Campaign, MCMA motor vehicles emit significant amounts of primary PM, particle-bound polycyclic aromatic hydrocarbons (PAHs), and a variety of air toxics such as formaldehyde, acetaldehyde, benzene, toluene, and xylenes.

Air pollution-related health effects in MCM

According to Cohen et al. (2005), air pollution causes approximately 3% of mortality from cardiopulmonary disease, approximately 5% of mortality from cancer of the trachea, windpipe, and lung, and approximately 1% of mortality worldwide from acute respiratory infections in children under the age of five. These impacts amount to about 0.8 million (1.2%) early deaths and 6.4 million (0.5%) lost years of life. Additional epidemiological studies have shown health consequences for total suspended matter (TSP), PM10, and PM2.5, with the latter being the most appropriate marker for health effects (Téllez-Rojo et al., 2000). Additionally, contemporary epidemiological research shows the impact of fine particles less than 1 m, including ultrafine (UF) particles (100 nm). Fine and UF particle masses are tiny in comparison to overall particle mass, but their number density, as well as their reactivity and hazardous effects, are important. Hence, the particle number density (number/cm3) is suggested in order to complete the characterisation of UF particles.

According to Cohen et al. (2005), air pollution causes approximately 3% of mortality from cardiopulmonary disease, approximately 5% of mortality from cancer of the trachea, bronchus, and lung, and approximately 1% of mortality worldwide from acute respiratory infections in children under the age of five. These impacts amount to about 0.8 million (1.2%) premature deaths and 6.4 million (0.5%) lost years of life.

Moreover, exposure to Mexico City smog has been linked to genetic harm in cell cultures. PM extracts, for example, cause DNA damage (Gutiérrez-Castillo et al., 2006); similar findings in human samples (Calderon-Garcidueas et al., 1996; Valverde et al., 1997; Rojas et al., 2000). Several of these air pollution-related health consequences share the generation or exacerbation of oxidative stress as a common harm mechanism. Oxidative stress is defined as a significant imbalance between reactive species (oxidants) generation and antioxidant defence that favours the former, potentially causing cell damage (Halliwell and Whiteman, 2004). Asthma, chronic obstructive pulmonary disease, arteriosclerosis, cardiac acute infarction, and diabetes mellitus have all been linked to oxidative stress. The organism has a battery of enzymatic antioxidants such as catalase (SOD), catalase (CAT), glutathione peroxidase (GPx), and paraoxonase (PON1) to counteract the severe damage caused by oxidative stress, as well as nonenzymatic antioxidants such as b-carotene, vitamin E, vitamin C, and sulfhydryl groups. SOD is a superoxide anion scavenge and one of the most important antioxidant enzymes in human cells, while GPx and CAT remove hydrogen peroxide.

The presence of damage in poly free fatty acids, proteins, and DNA, as well as the activity level of antioxidant enzymes, are other oxidative stress-related indicators. Myeloperoxidase (MPO) activity is a risk factor for cardiovascular disease (Aldus et al., 2003), nitroblue tetrazolium dye reduction (NTE) assesses protein damage, and thiobarbituric acid reactive substances (TBARS) and Alt and ast activity assess polyunsaturated free fatty acid damage (Medina-Navarro et al., 1997). C-reactive protein (CRP), ceruloplasmin (CP), and nitric oxide are further oxidative stress indicators (NO). CRP is an inflammatory marker that rises in response to trauma, infection, and other inflammatory stimuli. CRP is also a predictor of the development of cardiovascular disease, diabetes, and other metabolic illnesses. CP is an acute-phase protein that is generated in response to infection and inflammation. It is a serum a2-glycoprotein that transports more than 95% of the copper present in plasma. As a superoxide anion scavenger, it has anti-inflammatory properties. NO release is linked to a variety of disease conditions, including septic shock, inflammation, diabetes, and so on.

LAK (lymphokine-activated killer) cells

IL-4 regulates allergic responses mediated by activated mast cells and basophils, as well as CD8+ T lymphocytes, and it is essential for IgE synthesis. IL-4 reduces macrophage activation and prevents IFN-g effects, such as increased production of cytokines such IL-1, NO, and prostaglandins (Lucey et al., 1996). IFN-g creates an antiviral state, inhibits proliferation, and activates mononuclear phagocytes to destroy phagocytosed microorganisms. The two principal actions of IL-10 are the suppression of macrophage cytokine production (i.e., TNF, IL-1, chemokine, and IL-12) and the inhibition of macrophage accessory roles in T cell activation and B cell stimulation (O'Garra and Vieira, 2007).

It is generated by T and B lymphocytes, NK cells, and monocytes and is responsible for the differentiation route to Th1-type T cells as well as a precursor of the inflammatory response in cellular immunity (Trinchieri, 2003). The macrophage colony stimulating factor (GM-CSF) may boost both cellular and humoral immune responses, acting directly on T and B cells to induce differentiation (Gattoni et al., 2006).

High-risk populations

Certain MCMA population categories are more vulnerable to chronic air pollution exposure and are at a greater risk than others; these include youngsters, the elderly, and those who work long hours in outdoor places (Forastiere et al., 2007). In the MCMA, 2.7 million individuals are under the age of 18, with half of them living in poverty (INEGI, 2005). Kids are exposed to poverty, inadequate nourishment, and high amounts of environmental contaminants all at the same time.

Certain children's behaviours make them more vulnerable to pollutant insult; since they are more active than adults, children breathe more air, drink more liquids, and consume more food per unit of body weight. Due to the pleasant weather, MCMA youngsters physically participate in several hours of outdoor activities during the year (Landrigan and Anjali Garg, 2002). As a result, children absorb more air contaminants, which may hinder the formation of new alveoli (Etzel and Balk, 1999). Hazardous pollutant impacts, such as PAHs, carbon monoxide (CO), and lead, may also irreversibly harm children's development (Bearer, 1995). These problems may slow a child's growth and raise the chance of developing several chronic illnesses later in life.

When evaluating children for pollution-related health concerns, exposure to traffic (Herbarth et al., 1992) and interior exposures must be examined. Dust and volatile organic matter (VOCs) (Herbarth et al., 2001; Wolkoff and Nielsen, 2001) may have a role in the observed health consequences in all situations. Smoking and emissions from building materials and furniture are significant indoor VOC sources. These exposures have been shown to have an impact on inflammatory processes as well as allergy diseases in children.

According to Romieu et al. (2002), a 20 g/m3 rise in PM10 was associated with an 8% increase in lower respiratory diseases among children the next day, and a weekly mean of PM2.5 of 10 g/m3 was associated with a 21 g/m3 increase in lower respiratory tract infection. Calderon-Garciduenas et al. (2007) recently discovered that MCMA children had higher plasma endothelin-1, which is linked to an increase in pulmonary arterial pressure, a condition that may have an impact on their health in the future. When evaluating children for pollution-related health concerns, exposure to traffic (Herbarth et al., 1992) and interior exposures must be examined. Dust and volatile organic compounds (VOCs) may have a role in the observed health consequences in all situations. Smoking plus emissions from building materials and furniture are significant indoor VOC sources. These exposures have been shown to have an impact on inflammatory processes as well as allergy diseases in infants. According to Romieu et al. (2002), a 20 g/m3 rise in PM10 was associated with an 8% increase in lower respiratory diseases among children on the same day, and a weekly mean of PM2.5 of 10 g/m3 was associated with a 21 g/m3 increase in lower respiratory tract infection. Calderon-Garciduenas et al. (2007) recently discovered that MCMA children had higher plasma endothelin-1, which is linked to an increase in pulmonary arterial pressure, a condition that may have an impact on their health in the future.

A considerable share of the working force in less developed megacities, such as Mexico City, works in informal marketplaces, where many of them spend long hours outside. Many employees in the service and transportation industries face comparable challenges. In Mexico City, around 200,000 individuals work as taxi and bus drivers, and over 100,000 operate as street vendors (SETRAVI, 2007); they are directly exposed to mobile source emissions on high-traffic-density streets, resulting in considerable exposure to air pollutants (Ortiz et al., 2002). Outdoor workers in Mexico City are exposed to more PM2.5 than the Mexican limit of 65 g/m3, as well as two or more times more ozone and benzene, toluene, methyl tert-butyl ether, and n- pentane than interior employees. A study of outdoor workers in Mexico City discovered a link between their exposure to certain VOCs, O3, and PM2.5 with the occurrence of significant DNA damage. Many people are exposed to PM of vegetal, animal, or microbiological origin as a result of their work and home situations. Endotoxins, a prominent component of Gram-negative bacteria's outer membrane, are known to have harmful effects on human health when inhaled via airborne PM. Endotoxins may set off a chain reaction of biochemical and cellular processes that can lead to numerous dysfunctions associated with sick building syndrome or acute chronic lung illnesses (Jacobs, 1997; Rylander, 1999). Mycelium, mycelium, and metabolic products, on the other hand, are all allergenic chemicals that raise the prevalence of asthma and rhinitis in the exposed population.

The MCMA-2006 campaign

Megacities are substantial producers of air pollutants that impact regional and worldwide air quality, as well as the health of the vast people who live in them. According to some research, measures aimed at lowering air pollution would avoid tens of thousands of fatalities, medical visits by children, instances of chronic bronchitis, and millions of asthma attacks: events with a monetary worth in the billions of dollars. A global team of researchers conducted the Megacity Initiative: Local and Global Research Observations (MILAGRO) Campaign in and around Mexico City in 2006. This campaign consisted of four parts, each having a different geographic scale. Throughout the Mexico City Basin, the MCMA-2006 Campaign investigated pollutant emissions and boundary layer concentrations. The Megacity Aerosol Experiment in Mexico City (MAX-Mex) programme studied aerosol development and gas-aerosol interactions in the MCMA plume. The Effects of Megacities on Regional and Global Environments the Mexico City (MIRAGE-Mex) campaign investigated the development of the Mexico City plume on a regional basis. The INTEX-B programme tracked pollution evolution and movement on a continental scale.

MCMA-2006 used a mix of a central fixed site, mobile labs, fixed mobile units, and personal exposure monitoring to measure aerosol PM, VOCs, O_3, and other pollutant gas concentrations, as well as meteorological and sun radiation data, across the metropolitan region. Moreover, this experiment investigated children's and parents' exposure to air pollutants and health problems at three distinct descending sites intercepting the Mexico City air pollution plume and directing it towards the northern adjacent states of Mexico and Hidalgo. The first receptor site was urban, in

SE downtown Mexico City (T0)*; the second was suburban, in the State of Mexico, northern of Mexico City (T1); and the third was semirural, in Hidalgo State, northeast of Mexico City (T2).

The volunteers who participated in the study were children aged 9 to 12 and their parents; the youngsters were recruited from primary schools in the three districts. Before the campaign began, kids and their parents were given written and spoken information about the initiative, and they were asked to participate and provide their permission. Instructors were given important project information and urged to contribute. After the completion of the study, many information sessions were held to deliver the findings to the participants.

Ozone

Outdoor O_3 levels at residences and schools were three to six times greater than personal exposure and interior concentrations throughout the campaign. The semirural and urban locations had greater O_3 concentrations than the suburban site. T2 and T0 had higher mean home outdoor concentrations (189 and 166 ppb, respectively) than T1 (80 ppb); numerous observations above the 110 ppb 1-hour Mexican threshold. T2 and T0 concentrations were substantially lower inside than they were outside (18 and 28 ppb). Personal exposures for both children and adults were greater than indoor exposures but lower than outdoor exposures due to outdoor activities. The following were the results of a survey conducted by the University of Texas at Austin. Local production, plume oxidants delivered to the site, transportation time exposure, and work areas all had an impact on these exposures. For youngsters, personal exposure was greater at T0 (31 ppb), possibly affected by local O3 levels at the location and time outside This pollution level would still have a major influence on the local population's health.

Due to greater transportation exposures (longer commutes), high heavy vehicle density, and a higher secondary PM generation rate in the region, arents' PM2.5 personal exposure was higher at T1 (66 g/m3) and comparable at T0 and T2 (52 and 48 g/m3). The number of people exposed to pollutant-laden air in the United States has increased in recent years. Numerous readings were close to the 65 g/m3 24-hour Mexico threshold, which might have a severe influence on the health of the vulnerable local people. PM2.5 mass and number measurements were taken at home using direct reading monitors [Dust-Trak and Condensation Particle Counts (CPC)]. Mass concentrations assessed directly were those from filter samples, varied between 28.6 and 60.6 µg/m3 . Indoor values were greater at T2 and T1, but were comparable to outside amounts at T0.

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PM1 concentrations were greater outside than inside at all locations (9.48 vs 4.3 g/m3 at T2). The PM0.5 values were almost same outside and indoors (4.31 vs 4.06 g/m3 at T1). The outdoor PM0.25 concentrations were three times higher than the indoor values (9.50 vs 3.20 g/m3 at T0 and T1). The most abundant portion in all locations was the outdoor and indoor PM0.25 concentrations (50.67 vs 23.74 g/m3 at T1). Secondary PM creation and diesel vehicle emissions are primarily responsible for the production of a tiny proportion of PM. The lowest UF fractions in the MCMA may be linked to several health issues, such as the oxidative stress effects reported in volunteers.

Endotoxins

T0, T1, and T2 had mean outdoor endotoxin concentrations of 6, 8, and 19 U/ mg, respectively. Endotoxin concentrations in the home were greater at T2 than at T0 and T1, at 67.5, 14.11, and 2.94 U/mg, respectively. The concentration of endotoxin in pocket filters was greater at T0 than at the other locations. Due to entrainment of solid organic material residues, the high prevalence of outdoor endotoxins suggests considerable airborne levels of human and animal faecal coliforms and endotoxins. Endotoxin levels in dwellings reflect inadequate cleanliness and ventilation, particularly in rural areas. The greater endotoxin level in T0 personal samples might be attributed to these subjects extended outside time. These results are consistent with earlier research that showed the concentration range of aerosol endotoxin air.

Fungi

Outdoor fungal colonies were most common at T0, with the most isolated colonies [645 colony-forming units (CFU) separated]. T1 and T0 exhibited a comparable number of isolations for indoor samples, but T2 showed the largest isolation of fungal colonies for personal samples. The most isolated genus at outdoor, indoor, and personal levels was Penicillium sp. (41.2%, 20.68%, and 28.8%, respectively). The low frequency of fungus colonies may be attributed to the campaign's low humidity. There are several possible emission sources in rural regions, including plants, soil, and PM created by harvesting operations, with the wind acting as a medium for dispersing spores (Chen et al., 2004). Alternaria, Aspergillus, Cladosporium, Fusarium, Penicillium, and Rhizopus have all been identified as powerful allergen inducers (Nadel, 1980); several of these were isolated in this investigation. As a result, future research should link the quantities of these genes to the prevalence of asthma and allergies.

VO

The amount of exposure to VOCs from the city was determined by the distance from the city. The exposure rating at each measurement location was generally adults > children > apartments/homes > schools. Indoor VOC exposure was often greater than outside exposure outdoor VOC trends at the various sample locations were comparable. The primary constituents were toluene, limonene, and xylene. In most instances, T0 was the most contaminated site for every component, followed by T1 and T2, with the exception of limonene, which was greater at T1. Benzene and 1,3-butadiene exposures followed the same trend of indoor > outdoor > personal levels. Concentrations of 1,3-butadiene and benzene varied from 0.3-4 g/m3 and 2-10 g/m3, depending on sample location. A comparison of indoor and outdoor levels revealed greater interior concentrations, presumably attributable to cigarette smoke in certain residences. In general, personal sample levels mirror those obtained by equivalent stationary indoor or outdoor sampling findings. VOC levels in the MCMA were greater than in other metropolitan areas. It is worth noting that MCMA VOC emissions seem to have an impact on VOC levels in suburban (T1) and semirural (T2) sites and their adjacent regions. The discovery that T1 local VOC emissions comprise less than 0.04% of the State of Mexico's urban counties due to just seven industrial/commercial units recorded in a recent emissions inventory (SMAEM, 2004) supports this MCMA effect. There is no VOC emission inventory for T2, although local VOC emissions at that location are likely to be minimal [16].

Carbon Monoxide

The prevalence of respiratory disorders was significant; throughout the campaign, parents reported that 55% of their children had respiratory ailments at T2, with 20% having respiratory diseases at T1 and T0. Spirometry data revealed that the median flow (FEF25-75) was lower at T1 and T0. Children's observed health problems were most likely influenced by local levels of air pollutants, as seen by the disparities in reported levels at suburban and urban locations. Olfactory threshold data show that children from T0 have the lowest olfactory sensitivity. T2 children had the lowest thresholds. These criteria showed a 2.8-fold difference for T0 and a 1.6-fold difference for T1 Differences in olfactory thresholds may also imply that the negative impacts of air pollution on the olfactory system manifest early in life.

Oxidative Stress in Children

MPO enzyme plasma activity was considerably greater in T1 children than in T2 children (57.8 vs 47.7 U/mg protein), and the corresponding lipids damage indicated as lipoperoxidation products (TBARS) concentration was higher at T2 than at T0 and T1 (13.00, 9.01, and 9.44 M, respectively). PON1 enzyme activity was higher at T2 than at T1 and T0 (0.122, 0.103, 0.099 nmol p-nitrofenol/mg protein, respectively), and this coincides with the increased occurrence of carbonylation in T2 children than at the other locations. Lastly, the T1 site children had the lowest NTE decrease, indicating a poor antioxidant state.

A multivariate analysis was performed on a group of people who were involved in a variety of activities, including the production of a video game. NBT reduction was linked to benzene exposure and having a smoking mother, indicating a decrease in the antioxidant state associated with both exposures. TBARS generation was linked to PM10 exposure and a smoking mother. PON1 activity was linked to ozone and smoking parents, and MPO. The antioxidant enzymes GPx (77.10, 47.11, and 50.97 U/g haemoglobin at T0, T1, and T2, respectively) and SOD (1625, 1124, and 1510 U/g haemoglobin at T0, T1, and T2, respectively) were most active at T0. This might be an immediate reaction to increased levels of air pollution-related superoxide anion and superoxide anions. As a result, it's not unexpected that these people acquired antioxidant defences.

T2 had the greatest nitrite levels (71.59). Increased nitrite levels at T2 might be attributed to the activation of inducible isoforms of NO synthesis in leukocytes (neutrophils, eosinophils, basophils, and mononuclear phagocytes) (Abou-Seif and Youssef, 2004), because NO synthetase is expressed at very high levels in macro phages activated by exposures to bacterial lipopolysaccharide (LPS) (Sheffler et al., 1995), irritant air pollutants, or the usage of nitrite-rich food common in the

Mexican diet. The multivariate study of adults revealed substantial correlations between GPx and benzene, ozone, NO2, SO2, and residing near a factory. NO2, SO2, and the presence of new furnishings in houses were all linked to CRP. Nitrites were connected with 1,3-butadiene, pesticides, and PM10 exposures, while CP was correlated with 1,3-butadiene, dodecane, styrene, and new furniture

Polycyclic Aromatic

Modern technology's rapid progress has given us with a pleasant, safe, and prosperous way of life, but it has also presented us with possible health concerns in a far less obvious manner. Tobacco use, urban and industrial pollution, and the uncontrolled introduction of improperly labelled chemicals into diverse goods all contribute to the general population's exposure to chemical carcinogens. As a result, it is becoming clear that the issue of chemical carcinogens has progressed beyond its conventional context as an occupational danger to the point of being a possible concern to the general population. In recent years, there has been growing worry about the potential negative impact of hazardous substances in the atmosphere on human health. Chemical carcinogens in ambient air have received special attention.

Polycyclic aromatic hydrocarbons (PAHs) were among the first pollutants discovered as carcinogenic and mutagenic in the atmosphere (IARC, 1984). PAHs are common environmental pollutants found in the air, water, soil, and vegetation. They may also be found in distant and pristine environments. They are part of a class of substances known as persistent organic pollutants (POPs) and have received a lot of attention in recent years because of their intrinsic toxicity and tendency to disperse in the environment via direct emissions to the air and, as a result, long-distance transport. Several PAHs have the potential to cause cancer and mutations. The wording of this sentence is a little different from the one used in the movie. These are multiaromatic ring systems made up of fused aromatic rings of carbon and hydrogen atoms (linear, cluster, or angular arrangement.

The National Institute of Standards and Technology has listed 660 compounds of the PAH family (Sander and Wise, 1997), with around 30-50 of them routinely occurring in the environment. They are primarily formed in incomplete combustion processes, and their occurrence and emissions have therefore been significant throughout the ages due to the plentiful usage of fuels for industrial applications, heating, transportation, and a variety of other functions. As a result, PAHs are widespread pollutants in both the general environment and select workplaces. These are semivolatile chemicals found in both the vapour and particle phases of the atmosphere, as well as dissolved or suspended in precipitation. The majority of the more powerful carcinogens in this class contain more than three rings, therefore the term PAHs (or polynuclear aromatic hydrocarbons).

Structure and Properties

Surfactants, such as detergents, may significantly boost its solubility by forming micelles on the scale of 10-8 to 10-7 mol/L. Several organic solvents dissolve PAHs, including benzene, acetone, hexane, and tetrahydrofuran. They are also lipophilic, with lipophilicity rising with complexity.

PAHs have molecular weights ranging from 128 to 276 and boiling points ranging from 218°C to 525°C, with certain isomers having minor changes in boiling points. Vapor pressure normally decreases as molecular weight increases. Low-molecular-weight (LMW) PAHs with two or three fused rings are more volatile than HMW PAHs with more than three fused rings, which are typically associated with particles.

Carcinogenic PAHs of environmental concern evaporate quickly at higher temperatures and adsorb to particulate matter such as dust particles. The majority of PAHs are photosensitive and luminous under UV light, creating endoperoxides that thereafter suffer ring cleavage and dealkylation. There is some indication that PAHs adsorbed to particles are more susceptible to photooxidation. Certain PAHs may also be biodegradable, according to research.' They are generated by pyrolysis and pyrosynthesis methods.

Pyrolysis converts higher alkanes found in fuels and plant materials into PAHs. Reactive free radicals are created during pyrolysis at temperatures ranging from 500 to 800°C in the chemically reducing zone of a flame burning with inadequate oxygen. the mechanism of function. Aromatic ring systems are the most stable of the structural types present at pyrolysis temperatures, whereas aliphatic carbon-carbon bonds and carbon-hydrogen bonds easily break down to yield free radical molecular fragments, which then undergo recombination in the reducing atmosphere to form partially condensed aromatic molecules. The comparatively higher stability of aromatic rings allows for the steady buildup of condensed structural units as pyrolysis continues. In these circumstances, acetylene and butadiene chain extend, first to vinylcyclohexene and subsequently to the n-butylbenzene radical. After ring closure and dehydrogenation, a molecule of n-butylbenzene radical may engage a molecule of tetralin to generate 1-phenyl-4- (1,2,3,4-tetrahydro-5-naphthyl) butane, which subsequently releases BaP and benzo(j)fluoranthene. Several organic molecules, including acetylene, are generated during the heat breakdown process. It is not required, however, to assume that the pyrolytic production of BaP always requires initial breaking down to acetylene. Long-chain alkanes may be divided into C10 units.

The ability of aromatics to generate PAHs through pyrosynthesis rises in the following order: aromatics > cycloolefins > olefins > parafins. PAHs may also be generated during combustion by processes involving slow Diels-Alder condensations, fast radical actions, and ionic reactions. The radical creation process favours PAH formation inside internal combustion engines, and production is influenced by elements such as fuel type, oxygen content, and temperature. They are originally produced in the gaseous form at the source; at higher temperatures of combustion sources, greater amounts are present in the vapour phase. These PAHs condense from the vapour phase onto coexisting particulate substrates when the reaction mixture cools. PAHs may react with other pollutants in the atmosphere, such as NOx, SO_2, and others, to generate hetero-PAHs. These hetero-PAH compounds are more carcinogenic and mutagenic than their parent chemicals.

Natural Sources

Combustion (forest fires and volcanoes) plus biosynthesis (sediment diagenesis, tar pits, and biological conversion of biogenic precursors) are natural sources of PAHs (Oros and Simoneit, 2001a,b). They have a cosmic origin and may be found in coal tar, crude oil, creosote, and roofing tar.

The burning of biomass in wildfires is a natural occurrence on our planet and a significant main source of carbon and organic particulate matter, which alters atmospheric chemical, optical, and radiative characteristics through direct and indirect processes. Aerosol particles produced by fires may be both "solid" and "liquid." The generation of particles in flames starts with the synthesis of condensation nuclei such as PAHs from expelled gases and a range of "soot-like" species (Turns, 1996). The production of cyclic molecules and PAHs as nuclei in the flame zone is connected to the availability of double- and triple-bonded hydrocarbons in the biomass, and the creation of the initial aromatic ring is rate restricted. When the PAH molecules expand between 3000 and 10,000 amu through chemical and coagulative processes, these microparticles serve as condensation nuclei for other pyrolized species and may increase significantly. If temperatures approach 1100 K, many of these particles may be decreased in size by additional oxidation in the core of the flame zone.

Anthropogenic Sources

comprise both mobile and stationary types. The majority of mobile categories are vehicular (petrol and diesel engines) (Baek and Jenkins, 2004). Domestic heating, refuse burning, and agricultural and industrial activities such as metallurgical enterprises, foundries, and timber treatment plants, as well as companies focusing on the carbonization, distillation, and gasification of coal, coke, and aluminium, are examples of stationary categories. The impact of engine type is mostly dictated by the design of the combustion system, fuel-air combination, combustion chamber temperature, and manufacturing quality. It has been demonstrated that various cars using the same gasoline and running under the same circumstances may release dramatically varying levels of PAH (Velasco et al., 2004). Engine load, air-to-fuel ratio, and engine coolant temperature are the key engine operating characteristics that influence exhaust PAH content. The starting circumstances of cars' hot or cold engines have a small impact on the partitioning of PAHs in gaseous or particulate phases, with gasoline vehicles emitting more PAHs than diesel vehicles under cold start conditions (Devos et al., 2006). Diesel engines emit more particulate matter than gasoline engines and are the primary source of LMW PAHs, while light-duty petrol cars are the primary source of HMW PAHs such BaP and benzo(a,h)anthracene.

Marr et al. (1999) discovered a substantial link between the chemical composition and PAH emission rate in gasoline-powered cars, indicating that unburned fuel is a major source of PAH. The quantity of PAHs produced by gasoline cars is also affected by the air/fuel ratio; a leaner mixture produces less PAHs. Jones et al. (2004) discovered that when the air/fuel ratio increased, the amount of HMW PAHs dropped. Similarly, the composition of a fuel, as well as its PAH concentration, effects PAH emissions in diesel-powered automobiles (Ravindra et al., 2006b). In addition to vehicle exhaust, resuspended road dust from tyre, asphalt, and brake lining wear may contribute to PAH levels in the environment (Boulter, 2005). The PAHs released by these sources are mostly associated with coarse particles.

The largest source of PAHs in rail transportation is diesel/electric locomotives. The usage of coal-fired locomotives in poor nations may potentially add to PAH emissions. PAHs are also released from aircraft exhaust and rely on the volatility and content of the fuel, as well as the engine power setting (Chen et al., 2006). PAHs have also been observed to be released during shipping operations.

Coal combustion: Being a carbon-rich combustible rock, coal is an essential component of the energy supply that powers modern civilization. In addition, in addition to the fuel of choice for the most part, the fuel of choice for the most part is the fuel of choice for the most part. Coal is mostly made up of organic structures such aromatic clusters, aliphatic bridges and rings, side chains, and oxygen functional groups. Coal formations undergo significant physical and chemical changes when heated, releasing volatile organic molecules. The wording of the obituary is a little different, but the obituary is a little different too (Ni et al., 2003). There are two major elements that influence PAH emissions in coal.

The amount of PAH emitted by different coals is found to be related to their volatile content, and full combustion of coals with a high volatile content is more difficult to accomplish (Oanh et al., 1999). PAH emissions are also affected by the burning circumstances. Overall PAH emissions are primarily determined by the pyrolytic process and, to a lesser extent, by combustion efficiency. PAH emissions are also affected by the combustion temperature, quantity of air, and coal rank; emissions first increase and then drop as the temperature rises (Mastral et al., 2000). Also, a distinct PAH emission profile follows the combustion temperature. The concentration of PAHs in the petrol phase is greater than in the solid phase. The lower the total PAHs released, the greater the proportion of surplus air. A smaller amount of surplus air may encourage PAH deposition on more stable particulate matter, while a larger percentage of excess air may favour PAH transfer to the gas phase.

CHAPTER - 9

BIOFUEL COMBUSTION

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The smoke produced by biomass fuel burning is a complex combination of aerosols comprising substantial concentrations of carbon monoxide (CO), suspended particulate matter, lipids, and NOx (Naeher et al., 2005). In general, when biomass is burned, it emits a "chemical fingerprint" of natural (unaltered) and thermally altered (pyrolysis) organic constituents that are source specific and unique in composition; thus, they can be used as specific indicators for identifying fuel source inputs, ion channels, and receptor fate in samples of atmospheric fine particulate matter. During the burning of kulim (Scorodocarpus spp.) and seraya (Shorea spp.) wood, four-ring PAHs (e.g., fluoranthene and pyrene) and five- to six-ring PAHs (e.g., BaP and benzo(ghi) perylene) were found to dominate over two- to three-ring (e.g., phenanthrene). According to quantitative estimates of Indonesian forest fires, wood burning accounts for 25-35% of total PAH emissions in the Malaysian atmosphere (Okuda et al., 2002). Small-scale combustion, such as that of residential cook stoves, with a modest burning rate (a few hundreds of grammes to a few kilogrammes per hour), causes more PAH production, resulting in larger emission factors. This is due to the high volatile content of biofuels, which increases the chance of incomplete combustion.

Cigarette smoke is a complex aerosol with multiple classes of chemical compounds, 400–500 gaseous components and approximately 1010 particles ml-1 including numerous PAHs, and is a major source of particle-bound PAHs (PPAHs) in the indoor environment (Velasco et al., 2004). PAHs can be formed by degradation of organic cigarette components to simpler fragments followed by recombination of the simpler fragments during the pyrolysis processes in the burning cigarette. Guerin et al. (1987) observed that sidestream smoke is the major contributor while Baek and Jenkins (2004) observed the predominance of chrysene followed by benzo(a)anthracene and BaP in cigarette smoke. A commission by the California Air Resources Board found that the levels of PAHs associated with cigarette.

Chemical Transformations

PAHs are chemically inert substances. As PAHs react, they go through two sorts of reactions: electrophilic substitution and addition. The former is favoured since it preserves the aromatic character of the PAHs, while addition is often followed by elimination, resulting in net replacement. Numerous investigations have shown that several PAHs are photo chemically and chemically voidable under simulated air conditions. Chemical alteration of PAH s occurs as a result of gas particle interactions in emission plumes, exhaust systems, and even during atmospheric transit. PAHs react with other atmospheric pollutants such as O3, NO2, SO2, HNO3, and peroxyacetyl nitrate (PAN) and may create hetero-PAHs such as oxy, hydroxy, nitro, and hydroxylnitro PAHs when exposed to sunlight and molecular oxygen. Nitro and oxy PAH reaction products may exist in both the gas and particle phases. PAH molecules undergo important chemical processes such as nitration, ozonolysis, and photo oxidation.

PAHs react with O3 to generate mutagens with direct action, such as diones, quinines, and epoxides. They are photooxidized by the sun's UV radiation, producing mutagenic and carcinogenic reaction products such as aldehydes, ketones, and acids.

Photochemical reactions are widely regarded as the most significant method of PAH degradation in the atmosphere (Kamens et al., 1990). Nevertheless, PAH reactivity in the petrol phase is much higher than when linked with carbonaceous particle substrates (Esteve et al., 2006). Consequently, PAHs seem to be more stable when adsorbed on naturally occurring particles such as soot or fly ash than when present in pure form or in solution, adsorbed on silica gel or alumina, or coated on the glass surface. The production of species that are more hazardous, such as nitro-PAHs, or less toxic, as a result of PAH transformations on particles, might change. the toxicity of the particles. Heterogeneous interactions of PAHs on particles may modify their hydrophilicity and hence their ability to function as cloud condensation nuclei (Jones et al., 2004). Condensation may also coat newly released particles with secondary aerosol components generated by gas-phase processes. PAHs that are originally present on the surface of particles may become less accessible for reactions and less bioavailable as a result of this sort of change.

No photochemical Degradation

While irradiation seems to play a significant role in the degradation of airborne PAHs, light is not always necessary for PAH breakdown in the atmosphere. No photochemical processes, such as evaporative or oxidative interactions with gaseous contaminants, may potentially destroy PAHs. PAHs may also degrade in the atmosphere as a result of reactions with SOx or their acid counterparts, notably in aerosols or when adsorbed on particles.

Environmental Significance of PAHs and Their Effects on Human Health

PAHs are hydrophobic chemicals with long environmental persistence owing to their poor water solubility and electrochemical stability. Research shows that up to four or five fused benzene rings enhance the lipophilicity, environmental persistence, and genotoxicity of PAHs (CPCB, 2002). There is now substantial evidence that metabolically activated intermediates of carcinogenic hydrocarbons initiate carcinogenesis by binding covalently to DNA in target tissues, forming protein adducts, activating aryl hydrocarbon receptor (AhR)-mediated activity, and possibly interfering with oestrogen receptor (ER)-mediated signalling. After DNA replication, mutations occur, leading to carcinogenesis. The following is a list of the people who have been involved in the development of a new product or service. With a few exceptions,

Concerning carcinogenicity, the International Agency for Research on Cancer (IARC) classed three PAHs as "probably carcinogenic to people" and nine PAHs as "potentially carcinogenic in humans; insufficient evidence in humans; sufficient evidence in animals" (IARC, 1987). The carcinogenicity of PAHs is around 1/103-1/104 that of 2,3,7,8-tetrachlorodibenzodioxin (TCDD) (Machala et al., 2001); however, the PAH concentration in the atmosphere is approximately 104-106 times that of TCDD. As a consequence of the extensive occurrence and persistence of PAHs in the urban environment, human exposure to PAHs occurs mostly by direct inhalation, ingestion, or skin contact. The most major carcinogenic PAHs are BaP and pyrene, which are present in combustion processes, coke oven, foundry emissions, cigarette smoke, and charcoal-grilled meals. The majority of the evidence on the human health consequences of PAH exposure come from epidemiological studies done in the workplace.

Workers exposed to PAH mixes in coke ovens, coal gasification facilities, petroleum refineries, aluminium smelters, iron foundries, and with bitumen, diesel, and asphalt have an increased risk of lung cancer. The greatest PAH levels are most likely found in coke furnaces, while most epidemiological studies do not specify the quantities to which employees are exposed. Considering the long-term evidence that PAHs increase the risk of different malignancies, immunotoxic and pulmonary issues, a number of recommendations for human health protection have been developed. These proposals include removing or reducing emissions in workplaces, improving urban air pollution monitoring, and public education. The lack of research addressing this topic to date reflects the challenge of examining the health impacts linked with PAH exposure in the ambient air. A better knowledge of their origins and the atmospheric dangers presented by Pesticide exposure is therefore required.

Toxic kinetics

Bronchial clearance may remove debris from the airways. PAHs may be partially separated from particles during movement on the ciliated mucosa and may enter the bronchial epithelial cells, where metabolism occurs. When present as solutes in different dietary lipids, BaP and other PAHs are easily absorbed from the gastrointestinal system. The presence of bile salts in the intestine lumen aids in their absorption.

Through activating microsomal cytochrome P-450 monooxygenases and epoxide hydrolases, BaP and other PAHs increase their own metabo6lism. First, BaP is oxidised to various arene oxides and phenols Arene oxides may react covalently with glutathione, either spontaneously or when catalysed by cytosolic glutathione-S-transferases. The phenols may then be oxidised further to become quinones (1,6-, 3,6-, or 6,12-quinone). Moreover, secondary epoxides produced from phenols and dihydrodiols (diol epoxides) are created after further oxidation by the cytochrome P-450 mono oxygenase system (Graslund and Jernstrom, 1989). PAHs cause mutations and cancer by biotransforming into chemically reactive intermediates that bind covalently to biological macromolecules. Comprehensive and rigorous animal tumorigenicity research on specific PAH metabolites have led to the conclusion that vicinal or so-called bay-region diol epoxides are the ultimate tumor-causing and mutagenic species of alternant PAHs, albeit not necessarily the only ones (Graslund and Jernstrom, 1989). These diol epoxides are readily transformed into electrophilic carbonium ions by epoxide ring opening, which are alkylating agents that covalently link to nucleophilic sites in DNA bases and proteins.

Structure–Activity Relationship

The investigation of structure-activity connections began in the 1930s in an effort to identify the structural properties of chemical compounds that are responsible for their carcinogenic activity. Despite the fact that hundreds of compounds have been examined for carcinogenicity, it is clear that structure-activity connections are mostly unresolved and significant only within a certain class of chemical agents. Several broad structural properties shared by carcinogenic PAHs, for example, are known.

PAHs that cause cancer are basically planar compounds. Unsubstituted PAHs with just three rings are inert, while a few with more than six rings still exhibit some activity; there is a link between the molecular size of these compounds and their carcinogenicity. In general, an angular ring pattern (phenanthrene) with in molecule is required for carcinogenicity. The angular ring structure is of special significance because the centre ring includes a bond with the greatest double bond character, that is, it is more reactive than an ordinary aromatic double bond (e.g., 9,10 of phenanthrene; 5,6 of benz anthracene; and 4,5 of pyrene). The K-region was named after this connection. In addition to the K-region, certain PAHs feature a highly reactive area (L-region). For substitution processes, these carbon atoms are the most reactive. Pullman and Pullman (1955) proposed the K- and L-region theory, which stated that for a PAH to be carcinogenic, it must have a reactive K-region and an inactive L-region (inactivated by substitution or ring fusion); the K-region was concluded to be the site of critical reaction between the carcinogen and the cell constituents involved in carcinogenesis.

Boyland (1950) proposed that epoxides might be the reactive intermediate of PAHs Many investigations found that K-region epoxides are not more carcinogenic than their parent compounds, suggesting that the K-region is not implicated in the processes that lead to carcinogenesis. The critical molecular site. When two nonadjacent benzene rings, one of which is a benzo-ring, are in close proximity, a bay area forms in a PAH. Utilizing BaP as a model molecule, many research teams have independently concluded that the ultimate carcinogen of BaP is 7,8-dihydrodiol-9,10-epoxide, a bay-region epoxide (Marquardt et al., 1977). Based on perturbation molecular orbital calculations, diol epoxides are projected to be more reactive than K-region epoxides, while bay-region epoxides on saturated, angular benzo-rings of unsubstituted PAHs are predicted to be the ultimate carcinogens. Replacement of PAH ring hydrogen by substituent groups such as alkyl, hydroxyl, halogen, and so on may result in compounds with increased or decreased carcinogenicity, depending on the type of the substituent group and the location of substitution.

Health Impacts

Because of the constant nature of the exposures and the number of the population at risk, the presence of PAHs in urban air has generated significant worry. A variety of techniques have been established for assessing the potency of different PAHs in terms of potential human cancer risk from inhalation. The toxic equivalency factor (TEF), for example, evaluates the inhalation risk for excess lung cancer above the danger presented by BaP for each of its copollutant carcinogenic PAH in contaminated ambient air. The TEF technique has been widely utilised to estimate the danger of many kinds of hazardous chemical combinations. The overall toxicity or toxic counterparts (TEQs) of a combination are determined by the concentration of individual components (Ci) in a mixture multiplied by their relative potencies or TEFs.

The following assumptions are implicit in using the TEF approach: all individual compounds act through the same biologic or toxic pathway; the effects of individual chemicals in such a mixture are essentially additive at submaximal levels of exposure; dose-response curves for different congeners should be parallel; and the organotropic manifestations of all congeners must be identical over the relevant dose range. Individual TEFs are normally determined relative to the activity of a standard or reference chemical, and TEFi values are either generated for a species-specific reaction or are a composite value formed from TEFs for numerous responses. The TEF method has been used to study many structural groups of chemicals, such as PAHs, halogenated aromatic hydrocarbons (HAHs), and endocrine disruptors. Chu and Chen, as well as Clement Associates, were the first to create TEFs for PAHs (Nisbet and Lagoy, 1992). Nisbet and Lagoy ultimately consolidated and extended their work into a set of regularly used order-of-magnitude estimations. The applicability of this method was proven in mouse trials utilising very basic reconstituted PAH mixes.

Mutagenicity Assays

Around 100 in situ, short-term bioassays for identifying possible chemical mutagens and carcinogens are currently available, employing a range of cell types ranging from bacteria and phage to human cells. Several of these have been used to assess the mutagenicity of ambient fine particles as well as primary polycyclic organic matter (POM) emitted by motor vehicles, coal, and wood burning. The Ames/Salmonella Test, a short-term bacterial reverse evolution assay particularly developed to identify a broad variety of chemical compounds that might cause genetic damage that leads to gene mutations, is the most frequently used test to date. It is a quick and low-cost test that makes use of certain Salmo strains. This experiment employs S. typhimurium varieties that have previously undergone a mutation that renders them incapable of manufacturing their own histidine, as normal bacteria can. Exogenous histidine is therefore required for development of these bacteria. When exposed to mutagenic chemicals, these bacteria will return to their wild type and recover the capacity to manufacture histidine. As a result, when these bacteria are exposed to a chemical and cultured on plates containing limited histidine, only those microorganisms that have experienced the reverse mutation or reversion survive, while the unmutated ones starve owing to a shortage of histidine. The more bacterial colonies generated, the more mutagenic the chemical. Certain substances may cause mutations on their own or after being metabolically activated by bacterial enzymes. These are the mutagens that "directact." Some chemicals, particularly PAHs, need cytochrome P-450 system metabolism to be active. They are known as "indirectly acting" mutagens.6

As a result, we examine drugs with and without cytochrome P-450 enzyme preparations. The mutagenicity of extracts of ambient POM has been established in major cities worldwide. As with BaP, the majority of the activity is in submicron particles and is nearly entirely caused by frameshift-type chemical mutagens. The activities minus (-S9) and with (+S9) metabolic activation are roughly equivalent, although there are some notable changes. Ambient POM samples obtained near large frequently trafficked highways or motorways during rush-hour traffic, for example, indicate increased activity when S9 is introduced. Ambient POM collected in Stockholm, Sweden (Alfheim and Lindskog, 1984), Santiago, Chile (Adonis and Gil, 2000), Germany (Fielberg et al., 2002), Alaska (Watts and Wallace, 1988), and California has been shown to be mutagenic

(Archado and Archer, 1993). Extensive study on the chemical composition and carcinogenic and mutagenic effects of diesel engine exhaust emissions.

Standard Limits for PAH in the A

As a B-2 contaminant, indicator species are likely human carcinogens with significant evidence from animal research but insufficient evidence from human studies (CPCB, 2002). PAHs have been added to the World Health Organization's (WHO) list of priority pollutants in both air and water. WHO has established a recommend value of 1.0 ng m-3 (as BaP) for a one-year measurement period, but the Netherlands has established a guide value of 0.5 ng m-3 (as BaP) or a limit value of 5 ng m-3 (CPCB, 2002). The USSR Ministry of Health established the maximum allowed concentration (MAC) for BaP in industrial working zones as 15 mg/100 m3 and 0.1 mg/100 m3 in ambient air. The European Union has suggested that PAH indicator parameter (BaP) ambient levels be reduced to 6 ng m-3 by January 1, 2010. (CPCB, 2002). Before January 2005, the recommended ambient air quality standard for BaP in India was 5 ng m-3, and concentrations are scheduled to be lowered to 1 ng m-3 by January 1, 2010, at a rate of 1 ng m-3 per year.

Control Measures

PAHs cannot be completely eliminated; they can only be regulated. Modest steps such as eliminating superpolluting cars and reorganising the chaotic movements of buses in distribution centers would have a significant impact on air quality. Underground parking lots, such as those in business hubs, need special care since ventilation is poor and automobiles sit in lengthy lines. In the same way, diesel and heavy-duty vehicles must have their exhaust emissions and engines tested on a regular basis. These tests must be effective and concentrated in their use of particle traps on diesel vehicles and exhaust catalysts on gasoline vehicles.

Smokers, improperly calibrated pilot stoves, inadequate ventilation, and malfunctioning air-conditioning systems have all been identified as significant PPAH sources in areas such as houses, restaurants, and retail and entertainment centres. As a result, smoking must be prohibited in workplaces and hospitality facilities such as clubs and bars in order to protect the public from second-hand smoke exposure. PAH emission control standards are more difficult, necessitating an integrated strategy of emission control components/systems, engine technology, and fuel composition. Vehicle pollution contributes considerably to worldwide PAH emissions, and a variety of measures have been used to manage the efficacy of combustion, capture, and control of particle emissions. Catalytic converters for petrol engines have a significant influence on PAH reduction, which typically ranges between 80% and 90%, with the exception of BaP, which has a decrease of 94%. (Schauer et al., 2002). Catalytic converters for diesel engines cut overall PAH emissions, although not as much as those for gasoline engines (CONCAWE, 1998). To minimise particle emissions in heavy-duty diesel engines, turbocharging and intercooling with trap oxidizers and filters are being developed.

Because of the ambiguity in the emission parameters and the widespread prevalence of these activities, PAH emissions from agricultural sources are difficult to assess and manage. Yet, open burning of agricultural residue/waste may be controlled. In contrast, industrial sources are quite well recognised and increasingly controlled in industrialised nations. Indeed, better energy management may lead to better combustion, which leads to reduced emissions. Domestic sources of PAHs are widely distributed geographically, and PAH emissions are mostly uncontrolled. Several nations have rules in place to regulate the overall emissions from household heating systems. Contemporary gas and oil burners used in circulatory heating and hot water systems emit comparatively little PAHs. Similarly, automatically managed and fed solid fuel systems (e.g., wood, coke, and peat) are thermally more efficient (and emit less PAH) than hand-fed systems [17].

PAHs are classified as POPs. They are made up of hydrogen and carbon atoms organised as fused benzene rings with a linear cluster or an angular layout. There are hundreds of PAH chemicals in the environment, the majority of which are manmade. Individual PAHs, on the other hand, vary significantly in terms of their chemical and physical features. HMW compounds are generally less water soluble, less volatile, and more lipophilic than LMW ones. They are resistant to degradation, may persist in the environment for extended periods of time, and have the potential to harm the ecosystem and human health. Because of their severe mutagenic, carcinogenic, and toxic qualities, PAHs are recognised as priority pollutants by the US EPA and the European Commission. The most well-known moral chemical in this class is the extremely carcinogenic BaP.

Cellular Mechanisms behind Particulate Matter Air Pollution

Urban air pollution is a big issue that affects millions of people worldwide. The World Health Organization (WHO) has estimated that it is responsible for 865,000 annual deaths and 1.1 life lost due to premature mortality (DALYs)/1000 capita each year in urban environments globally (WHO, 2007). The majority of the data relating air pollution to human illness has come from epidemiological research (Samet and Krewski, 2007). The major health issues associated with air pollution are adverse health conditions and diseases affecting the respiratory and cardiovascular systems of susceptible groups, such as children, the elderly, and those with underlying cardiopulmonary ailments. Increased cardiopulmonary mortality, asthma worsening, chronic obstructive pulmonary disease (COPD), and reduced heart rate variability are among the health endpoints

Such examples include hypercoagulability, reduced lung function development in children, and lung cancer (Kunzli and Tager, 2005; Pope and Dockery, 2006; Samet and Krewski, 2007). Increasingly, focus has shifted to health consequences that impact other systems, such as low birth weight (Bell et al., 2007) and the induction of chromosomal abnormalities in infants (Pedersen et al., 2006). All of these impacts have been linked to at least one of the so-called criterion pollutants that are regularly assessed to evaluate air quality in the majority of cities throughout the globe. Airborne particulate matter (PM), ozone (O3), sulphur dioxide (SO2), nitrogen oxides (nox (NO2), carbon monoxide (CO), and lead (Pb) are examples of criteria pollutants (US-EPA, 2006). Since that this chapter is about PM, a description of this pollutant will come next.

PM is a complicated combination of solid and liquid components that may vary greatly in size, substance, and form. The aerodynamic diameter of PM varies from 0.005 to 100 m. (total suspended particles, TSP). In most metropolitan areas, PM is measured as PM10 (particles with a mean aerodynamic diameter of 10 m) and/or PM2.5 (particles having a mean aerodynamic diameter of 2.5 m). PM10 particles are inhalable and are divided into four fractions: fine, fine, ultrafine, and nanoparticles. The coarse or thoracic fraction has an aerodynamic diameter of 10 to 2.5 m (PM10-2.5); tiny particles are known as the respirable fraction (PM2.5); ultrafine particles (UFPs) have a diameter of less than 0.1 m; and nanoparticles have a diameter of 50 nm or less. The size of particles determines their capacity for deposition and clearance in the respiratory tract, which is critical for causing negative health consequences.

Particle composition changes depending on particle size and emission source. Metals, organic compounds, ions, condensed reactive gas products, microbes and microorganism products (e.g., endotoxins), nitrates, sulphates, and elemental carbon, among other things, may be found in particles (Pope and Dockery, 2006). Fine particles and UFPs are made up of a fundamental carbon structure, metals, hydrocarbons, and secondary particles. Sulfates, nitrates, and organic chemicals generated by condensation of high-temperature vapours or atmospheric chemical interactions of nitrogen oxides, SO2, volatile organic compounds (VOCs), and other reactive molecules are among the latter (Hinds et al., 1985; HEI 2002). The coarse fraction, on the other hand, is created mechanically and is mostly constituted of insoluble mineral oxides, hydroxides, sulphates, carbonates, halides, and so forth; it may also include organic stuff, such as pollen and spores. Bacteria and viruses have been discovered in both the fine and coarse fractions.

There are several sources of air particle emissions, which are caused by both natural and manmade activity. Dust storms, volcanic activity, forest fires, erosion, and other natural causes are examples. High-temperature metallurgical and combustion operations employing wood, paper, oil, coal, or other fossil fuels are examples of anthropogenic sources. Automobiles and buses, as well as power plants and industrial operations, are the primary sources of emissions in metropolitan areas (Molina et al., 2004; Molina and Molina 2004).

The current state of knowledge on the health impacts of PM is poor. PM toxicity is most likely determined by their physicochemical features, which include size, shape, content, and reactivity. The current research is inconclusive on the exact PM features that cause poor health effects and toxicity. While the risk of different harmful health consequences rises with PM exposure, there is no evidence to propose acceptable levels or a threshold beyond which adverse outcomes would not be predicted. It is crucial to highlight that health impacts have been observed at concentrations that are not significantly higher than background levels, with PM2.5 concentrations in the United States and Western European locales estimated at 3-5 g/m3. Moreover, recent information shows that negative consequences occur in cities all over the world, including North and South America, Europe, and Asia.

Despite the fact that available epidemiological research shows that particulate matter (PM) is the air pollutant with the most persistent and stronger links with a variety of poor health outcomes, we are still far from understanding the processes involved. Moreover, it is unclear whether the claimed detrimental health consequences should be completely ascribed to some of the particular components of PM, to its composite mixture, or if PM is a proxy for the wider complex multi-air pollutants matrix. The existing evidence is mostly based on criterion pollutants data. Yet, it is obvious that air pollution encompasses a diverse set of compounds, including "hazardous air pollutants" (HAPs). Metals such as cadmium and mercury, as well as organics such as benzene and polycyclic aromatic hydrocarbons (PAHs), are examples of HAPs (US-EPA 2006). While certain HAPs have lately been tracked in specific places, it is not a typical practise. According to new research, the components of air pollution vary by city and, within a city, by geography and season (Dominici et al., 2005). This raises the issue of whether unfavourable health consequences from air pollution are the result of individual component exposure or of complex interactions among contaminants. We must improve our capacity to gather data on numerous contaminants and create approaches to analyse the impact of mixtures on chronic multiple disease processes linked with air pollution exposures.

Uncertainties associated with epidemiological study findings, such as difficulty establishing causality, identifying thresholds, assessing biological plausibility, identifying mechanistic partnerships, assessing effects of pollutant mixtures, and so on, necessitate complementary experimental research. Developing the evidence needed to identify and address environmental health concerns might take many steps.

There is an opportunity for experimental research focused on understanding insights into the mechanisms, the role of relevant physiological components, and the cellular mechanisms involved in the causation of adverse health effects, in addition to estimating population exposures and evaluating the relationship with potential health effects (epidemiology). The current knowledge of the health impacts of air pollution did not emerge by following the straight route shown in the picture. Prior research, on the other hand, has enabled the use of scientific data to conceive and construct policy initiatives and regulatory measures that, although far from comprehensive, have been effective in mitigating the issue in a number of cities throughout the globe (UNEP, 2007). Maximum particle and ozone concentrations, for example, have reduced dramatically in several megacities, and national ambient air quality regulations are less commonly surpassed (Molina et al., 2004; Molina and Molina, 2004). This is the situation in the Mexico City Metropolitan Area (MCMA), where increasing fuel quality and implementing improved automobile pollution control technology (such as three-way catalytic converters), among other measures, have helped improve air quality.

CHAPTER - 10

PULMONARY EFFECTS OF PM

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It is obvious that an inhaled particle has the greatest influence on the respiratory system. Particles may reach the upper airways (TSP), lower airways (PM10), or alveoli (PM2.5 and ultrafine PM) depending on their aerodynamic size, or they can be translocated out of the respiratory tract and cause systemic harm (nanoparticles). Smaller particles may be deposited in the airways with a nonhomogeneous depositional pattern, according to mathematical models validated b6y animal experiments (Balashazy et al., 2003). Recent research indicates the presence of target hotspots, or high PM concentrations at bronchial and bronchiolar bifurcations (Balashazy et al., 2003). . This is critical for analysing the in vitro data since PM concentrations at deposition hotspots may be comparable to those employed in the in vitro study. Another factor to consider is the difficulty in obtaining representative PM samples for experimental research that cover important size ranges and are typical of various sources. As a result, some groups have employed surrogate particles (e.g., residual oil fly ash—ROFA) to assess the role of size, physicochemical features, or composition, whilst others have used actual real-world urban PM.

Studies have been carried out to identify the cellular players and processes involved in the response to PM exposure. the event sequence schematically. Particles will interact with macrophages or epithelial cells when they enter the lungs. The presence of PM causes cell responses that can be mediated by cellular receptors. These cell responses result in cell recruitment to remove deposited particles, the secretion of inflammatory factors (e.g., cytokines), or tissue remodelling (e.g., fibroblast/myofibroblast recruitment/proliferation). If particles are not eliminated, they may cross the epithelial barrier with the aid of dendritic cells or by intersex transport, causing impacts on the interstitium or even beyond. They may enter the circulatory system and activate artery endothelial cells, as well as distant organs. In the sections that follow, we will discuss the function of molecules and cells that seem to play critical roles in the biological response to PM exposure.

Of the many chemicals found on the cell surface, two have been identified as playing an essential role in the response of epithelial cells and macrophages to PM exposure. TLR-2 and TLR-4 are Toll-like receptors (TLRs) that belong to the TLR family, which has 11 members. TLR-4 is one of the most researched members of the TLR family, and it reacts to the presence of endotoxins, which are chemicals found in gram-negative bacteria. TLR-2, on the other hand, reacts to lipoproteins. Peptidoglycans are peptides found on Gram-positive bacteria (Tsan, 2006). The functions of these two receptors in response to PM exposure differ; macrophages react through the TLR-4 receptor, whilst epithelial cells respond via the TLR-2 receptor (Becker et al., 2005b).

When the TLR-2 receptor is blocked by an antibody on epithelial cells exposed to PM, interleukin-8 (IL-8) production is decreased, but no inhibition is found when the TLR-4 receptor is inhibited directly or indirectly. In the case of alveolar macrophages, inhibiting TLR-4 inhibits the release of interleukin-6 (IL-6). This demonstrates that the response of two distinct cell types (macrophages and epithelial cells) to PM is linked to distinct pathways, with distinct results (IL-6 versus IL-8 secretion). It is unclear whether these reactions are exclusively due to the presence of lipopolysaccharides (endotoxins) or gram-negative bacteria in PM, or whether they are the consequence of the activation of other molecules, such as heat shock protein 70 (Hsp70), which are also activated after PM exposure.

Cytokines are another class of chemicals that play an important role in the immune response to PM exposure. Cytokines are a class of peptides and proteins that cells employ as signalling molecules to interact with one another. Different cytokines are associated with distinct activities in the inflammatory reaction. To provide an example, they organise the sequence of events that leads to cell recruitment (e.g., monocytes) through endothelial cell activation, which is required for subsequent cell migration into the tissue (Male et al., 2006). Many cytokines are involved in the cell response to PM.

TNFa, IL-6, and IL-8 are three cytokines that have been repeatedly described as essential players in the response to PM. Others, such as interleukin-1b and interferon g (IFNg), play critical roles in the immune system. Growth factors, such as granulocyte colony-stimulating factor (G-CSF) and granulocyte macrophage colony-stimulating factor (GM-CSF), growth factor receptors, such as platelet-derived growth factor receptor a (PDGF-Ra), and cell recruiting chemokines, such as monocyte chemotactic protein-1 (MCP-1) regulated upon activation, normal T-cell expressed and secreted (RANTES), macrophage. TNFa, IL-6, and IL-8 were the first cytokines related to PM exposure, as previously stated(Monn and Becker, 1999; Alfaro-Moreno et al., 2002). TNFa is a chemical that causes a variety of inflammatory reactions, including the activation and recruitment the inflammatory cells and the activation of endothelial cells.

TNFa levels increase the production of IL-6, which is also a proinflammatory cytokine. Yet, increasing IL-6 inhibits TNFa, resulting in a feedback loop between these two molecules. Nevertheless, IL-6 release during PM exposure may be independent of TNFa secretion. Exposure cells to PM10 collected from various MCMA sites, which are linked with varied emission sources and chemical composition, leads in different patterns of triggering TNFa and IL-6 production. TNFa expression was unaffected by PM location, but IL-6 exhibited a 5-fold variation depending on PM location. These findings suggest that IL-6 production from PM10 exposure is not totally dependent on TNFa release and that changes in PM composition may play a role in eliciting biological consequences.

TNFa is mostly released by macrophages, however it may also be produced by epithelial cells. TNFa stimulates the production of IL-6 by other cells and may also stimulate the production of IL-8, RANTES, growth regulated oncogene-alpha (GROa), GM-CSF, and G-CSF. TNFa is a well-known endothelial cell activator, increasing the production of adhesion molecules and aiding the migration of eosinophils. When IL-8 secretion is increased, neutrophilia rises. G-CSF and GM-CSF are cytokines with systemic effects. TNFa is not the sole factor that may cause cytokine upregulation. Endotoxins play an essential function as well. Endotoxins may cause the production of MIP-1a and IL-1b, which in turn can cause the expression of other cytokines). MIP-1a, for example, stimulates the secretion of TNFa, IL-1b, and IL-6, while IL-1b stimulates the production of G-CSF, GROa, IL-8, and MCP-1. The many mediators indicated above have been linked to in vivo and in vitro PM exposures; however, the order in which they are secreted and the relative role of different cells in the regulation, amplification, and inhibition of each mediator remain unknown.

Translocation of PM

A key topic about PM effects is how they cause effects outside of the respiratory tract or beyond the airway epithelial barrier. To answer this issue, at least three ideas have been presented.For starters, the production of inflammatory substances by macrophages and epithelial cells in the lungs may activate distant cells such as endothelial cells. TNFa, for example, may cause endothelial cells to become dysfunctional. Finally, PM may overcome the epithelial barriers and enter the circulation after passing through the endothelial barrier. Many investigations have shown the possibility of PM translocation, albeit the processes are not entirely understood.

Nemmar et al. (2002a) demonstrated that persons treated by inhalation to nanoparticles tagged with technetium-99 exhibited a radioactive signal in the bladder and liver. These findings are contentious since another investigation found no evidence of particle transfer. This negative finding might be attributed to particle clumping and/or the authors' choice of nanoparticles, since other research employing animal models revealed the presence of PM translocation following intratracheal instillation. There are two primary ideas that aim to explain how PM may translocate to other places. Some data implies that epithelial cells absorb particles and translocate them into lung capillaries (Kato et al., 2003). (Kato et al., 2003). Recently, the function of dendritic cells in PM translocation has been established in vitro These scientists show that dendritic cells are capable of penetrating the epithelial barrier, phagocytizing the particles and translocating them to the opposite side of the barrier. These findings may be significant for asthmatics and allergy people, who have larger numbers of dendritic cells.

Several writers believe that PM diffusion may occur. Geys et al. (2006) found that the intercellular epithelial cell connections (tight junctions) are lost temporarily after adding PM. This research implies that PM may translocate between the cells rather than through the cells. Whichever be the translocation mechanism, once particles translocate into the interstitium they might engage fibroblasts, activating them and triggering airway remodelling. We have previously demonstrated that PM upregulates the expression of PDGF-Ra (Bonner et al., 1998), making myofibroblasts more prone to migration and proliferation following stimulation with PDGF. These data reveal substantial associations between PM exposure and higher risk of developing COPD.

Extrapulmonary Effects Induced by PM

Persistent exposures to PM have been positively connected with unfavourable extrapulmonary health effects. For instance, the cohort study conducted by the American/Cancer Society with over a 16-year follow-up reported that a PM2.5 elevation of 10 μg/m3 increased the risk of ischemic heart disease by a factor of 1.18 (95% CI: 1.14–1.23), and that the risk of mortality related to arrhythmia, heart failure, and cardiac arrest increased the risk rate of return to 1.13 (95% CI: 1.05–1.21) (Pope et al., 2004). (Pope et al., 2004). Similarly, the classic Harvard Six Cities research (Dockery et al., 1993), indicated an adjusted mortality-rate ratio for the most polluted city compared with the least polluted one equal to 1.25 with the highest influence of fine PM on cardiovascular-related fatalities.

The generation of endothelial dysfunction phenotype by PM has been shown in vitro and in vivo. Endothelial cells exposed to PM show upregulation in the expression of E-selectin, P-selectin, intercellular adhesion molecule 1 (ICAM-1), platelet vascular endothelium adhesion molecule (PECAM), and vascular endothelial cell adhesion molecule (VCAM) 2007). The expression of these molecules is related with increases in the adherence of monocytes to the endothelium monolayer. In vivo investigations by Nemmar et al. (2007) indicated that P-selectin plays a significant role in the inflammatory and prothrombotic effects caused following intracerebroventricular instillation of carbon nanotubes in a mice model. Another in vivo investigation demonstrated that following intratracheal instillation of ROFA in rats, systemic vascular dysfunction was seen, in addition to the local inflammation in the lung**.**

Several studies have demonstrated that clotting formation is connected to exposure to PM. revealed that the intravenous injections of positively charged (amine-modified) polystyrene particles with 60 nm diameter generated an increase in the prothrombotic propensity assessed in the femoral vein in a hamster model. This effect was partly attributable to platelet activation. They obtained comparable findings when the particles were administrated via intratracheal instillation

These findings have been replicated independently using an auditory vein thrombosis model Surprisingly, the introduction of negatively charged polystyrene particles did not generate an increase in clotting processes, confirming the concept that the composition of PM plays a key role in the associated consequences. Additional investigations have demonstrated that the use of surrogate PM, such as diesel exhaust particles (DEPs), promotes substantial pulmonary inflammation, accompanied by enhanced venous and arterial thrombosis and platelet activation, 1 h after their deposition in the lungs (Nemmar et al., 2003b) (Nemmar et al., 2003b). These effects last for 24 h after the instillation. The mechanism of these prothrombotic effects appears to be connected to the histamine receptor (H1-receptor) (Nemmar et al., 2003a) (Nemmar et al., 2003a). Stabilization of mast cells inhibited these effects, indicating that mast cells may play a significant role in the inflammatory and the prothrombotic effects (Nemmar et al., 2004). (Nemmar et al., 2004). The cross communication between macrophages and neutrophils appears to be significant. Neutrophil enzymes may be important for the priming of platelet activation and may contribute to the development of a thrombotic tendency (Nemmar et al., 2005). (Nemmar et al., 2005). Lately, the involvement of IL-6 in the prothrombotic effect of PM has been studied.

When mice were exposed to PM10, bleeding times were decreased, however when IL-6 knock out mice were exposed to the same particles, the animals' bleeding time was not reduced (Mutlu etal., 2007). (Mutlu etal., 2007). Tissue factor is another molecule associated to the regulation of clotting formation; it affects the extrinsic route of the blood coagulation cascade. Karoly et al. (2007) exposed pulmonary artery endothelial cells of humans to UFPs and an elevation in the expression of the tissue factor after 2 and 24 h of treatment was found. Surprisingly, soluble and insoluble portions of the UFPs were capable of eliciting identical effects.

Utilizing an apoE-/- mice model (apolipoprotein E knock out animal that has been used as an atherosclerosis model), Sun et al. (2005) found that long-term exposure to low concentrations of PM2.5 affected the vasomotor tone and produced vascular inflammation and atherosclerosis. Several investigations have demonstrated that PM is related with increases in endothelin-1 levels in vivo and in vitro Endothelin-1 is responsible for induction of vasoconstriction, and has been connected to pulmonary and cardiovascular diseases (Luscher and Barton, 2000). (Luscher and Barton, 2000). A group of MCMA children chronically exposed to urban pollution was compared with a population of children residing in a town with comparable geographical characteristics but with substantially lower levels of air pollutants. The youngsters from Mexico City showed elevated endothelin-1 plasma levels, which were associated to mean pulmonary arterial pressure. The children involved in the research were clinically healthy; a lengthier follow-up of these groups may assist to better identify risk factors related with pulmonary hypertension. Even if particles never reach the lungs, they may have systemic consequences. Elder et al. demonstrated the effect of inhaled PM on the neurological system (2006). These researchers looked at changes in breathing patterns, heart rate, and rate variability and discovered that UFP might enter the central nervous system through the lungs. Neuronal olfactory pathway.

Oxidative Stress Induced by PM

The key mechanism mediating PM-induced biological impacts has been considered to be oxidative stress (Kunzli and Tager, 2005). Oxidative stress refers to a broad range of circumstances that alter cellular redox state. Oxidative stress is characterised as an imbalance in the body's oxidant and antioxidant reactions. An organism with elevated oxidants, resulting in an increase in the amount of reactive oxygen species (ROS) at the intracellular level. Asthma and COPD (Tao et al., 2003); genotoxicity and tumour promotion (Knaapen et al., 2004); vascular changes and hypertension (Peters, 2005); and neurodegenerative illnesses such as Parkinson's and Alzheimer's disease have all been linked to oxidative stress.

Yet, exposure to air pollution may lead to negative health effects. SO2 is a colourless asphyxiating gas that is produced during the burning of sulfur-containing fossil fuels. It is a reducing agent rather than an oxidising agent. It is not a free radical since it lacks unpaired electrons. It may, however, react with water and oxidants to make sulfite, sulphate, and bisulfate ions, as well as sulfite, sulphate, and bisulfate radicals, which can induce lung injury and bronchoconstriction (Halliwell and Gutteridge, 2007). Ozone is a very unpleasant colourless gas with a distinct odour; it is a highly oxidative pollutant but is not a free radical. Modest levels of O3 (0.5 ppm) may induce lung damage in a matter of hours by triggering inflammation, activation of alveolar macrophages, and neutrophil migration.

By targeting sulfhydrl groups (-SH), tyrosine, histidine, and methionine residues, ozone may damage proteins. O_3 may also directly target lipids. Human nasal secretions are high in urates, which react with O_3 and NO_2 to cause nose discomfort. Reduced antioxidant cellular activity or the lack of antioxidant cellular components adds to the exacerbation of oxidative cell damage caused by PM, SO_2, and O_3. Cellular exposure to oxidants, such as pollution in the environment, results in a coordinated cell response in which gene activation of antioxidant enzymes is a significant component. Several of these proteins are enzymes that participate in the antioxidant response, helping the cell to protect against ROS by:

In rat lung epithelial cells exposed in vitro to PM, cytotoxicity, malondialdehyde formation (a product of lipid peroxidation), and induction of apoptotic cell death were associated with compensatory increased expression of antioxidants such as CAT, metallothionein, and the Nrf-2 transcription factor A reversible increase of lipid peroxidation and antioxidant enzymes in the heart and lung was seen in rats exposed to concentrated fine PM for 5 hours, indicating an adaptive response to acute exposure (Gurgueira et al., 2002). In another research, rats exposed to extremely high levels of fine PM (7.5 and 37.5 mg/kg) exhibited enhanced lipid peroxidation in organs such as the heart, liver, lung, and testicles, but a substantial decrease in SOD, CAT, and GPx activities in the lung, liver, organs, and brain. GSH levels were found to be depleted. Although this systemic toxicity affecting the respiratory and cardiovascular systems was attributed to a prooxidant/antioxidant imbalance (Liu and Meng, 2005), it is important to investigate changes in the pro-oxidant/antioxidant balance using smaller doses that are more representative of "real-world" exposures.

After in vitro and in vivo exposure to different particles such as ROFA, DEPs, quartz particles, and ambient PM, macrophages and phagocytes generate ROS through mitochondrial mechanisms. Mitochondrial processes implicated include respiration through NADPH enzyme activation, the respiratory burst, and inducible nitric oxidase synthetase activation (iNOS). As ultimate cellular outputs including oxidative stress, these mechanisms translate into cytotoxicity, irritation, DNA damage, and encouragement of cellular proliferation

Carcinogenic Responses Induced by PM

A noteworthy epidemiologically established health consequence associated with PM exposure is a consistent link with cancer mortality rates (Pope et al., 2002). As compared to other established risk factors, such as smoking, the stated risk (8% higher risk of lung cancer mortality per 10 g/ m3 rise in PM2.5 concentrations) is rather minor. It is, nevertheless, a noteworthy finding since it is tied to nonvoluntary exposures and adds another health worry to the list of problems associated with air pollution. This raises additional questions about the underlying mechanics. Several potentially carcinogenic compounds are found in air pollution, including benzo [a] pyrene, benzene, 1,3-butadiene, dioxins, metals, oxidants such as ozone and NO2, as well as sulphur and other nitrogen oxides. Some of them may include particle components (Kyrtopoulos et al., 2001; Aust et al., 2002; Cohen, 2003; Sorensen et al., 2003; Knox, 2005), but their proportional contribution to increasing lung cancer mortality remains unknown.

Nevertheless, methodological constraints prohibit establishing conclusive findings about causality. Yet, fresh research suggests that there are strong links between ambient PM exposure and different malignancies, including paediatric cancers (Knox, 2005), gastric cancer (Sjodahl et al., 2007), and melanoma to understand the links between cancer mortality and air pollution exposures, we need additional information, particularly monitoring data from a broader range of contaminants. PM is recognised as the key risk factor linked with increased lung cancer mortality risk among regularly measured air pollutants, however detailed mechanisms have not been found. Induction or inhibition of a number of metabolic enzymes (e.g., CYPs, GST, tyrosine kinase, etc.), disruption of homeostasis through oxidative stress, organelle dysfunction, ionic channel interference, signal transduction interference, changes in hormone-receptor interactions, and interference with growth and differentiation may all be examples. These mechanisms may cause cytotoxicity, DNA damage, mutagenicity, and proinflammatory cytokine production (Lee and Lee, 2006; Valko et al., 2006). One important mechanism hypothesised to generate a procarcinogenic milieu in the cell is oxidative stress. While there is substantial evidence that ROS/reactive nitrogen species (RNS) cause particle-induced genotoxicity and instability, little is known about the following processes that lead to neoplastic alterations. Particles and particle-elicited processes, such as activation of inflammation and proliferation pathways, have been proposed as key participants in particulate cytotoxic effects, mutagenesis, and carcinogenesis.

The majority of these investigations focus on understanding pathways involving organic substances such as PAHs, dioxins, or metals Yet, we must remember that PM is not a single component pollutant, but rather a combination of pollutants from multiple sources that varies in composition and reactivity on a continual basis. There are two types of genotoxic lung cell damage caused by PM: primary and secondary genotoxicity. In the absence of pulmonary inflammation, primary genotoxicity is characterized as genetic harm caused by particles. Secondary genotoxicity refers to a kind of genetic damage caused by oxidative DNA assault by ROS/RNS produced during particle-induced inflammation. Inflammation has long been linked to the development of cancer in other places.

In theory, primary genotoxicity might occur via a variety of pathways, including ROS action (e.g., as created by reactive particle surfaces) or DNAadduct production by reactive metabolites of particle-associated chemical substances (e.g., PAHs). Presently, scientific literature only suggests that cancer caused by weakly soluble particles such as TiO_2, black carbon, and DEPs includes a secondary genotoxicity pathway. The cell's reaction to genotoxic stress may vary depending on the cell type being insulted, the toxicant concentration, and the period of exposure. While mutagenic pathways are known to have a part in many forms of cancer, assessing the mutagenicity of air pollutants must be done carefully owing to the dynamic interactions that occur in such a complex combination of contaminants (Claxton and Woodall, 2007). Particulate air pollution are often carcinogenic, according to epidemiological studies (Claxton and Woodall, 2007; Yauk et al., 2008). Variations in the responses of different [18].

To retain DNA integrity and, as a result, avoid cell malfunction and uncontrolled growth and proliferation, genotoxic cell damage necessitates compensatory cellular actions. Cell cycle regulation, DNA repair, and apoptosis are just some of the processes involved in cell survival and maintenance of a nonneoplastic acceptable destiny. As part of the DNA damage-control pathways, the tumour suppressor protein p53 plays a critical role in preserving genomic integrity. After PM experimental exposure, p53 is a significant marker for cell cycle regulation and death. Cells exposed to PM upregulate p53, and p53 overexpression coincides with the activation of apoptosis (Garca-Cuellar et al., 2002). (Soberanes et al., 2006). Further research is needed to fully understand the involvement of this protein in PM-induced DNA damage and carcinogenic pathways.

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Epigenetic changes affect gene expression rather than gene sequence by packing and unpacking the DNA. DNA methylation and post-translational histone protein modifications including acetylation, methylation, ubiquitination, signal transduction, and phosphorylation are two biological pathways that mediate epigenetic events. Alteration in DNA methylation status are commonly linked to cancer development. DNA methylation may have a role in carcinogenesis via a variety of methods. Hypermethylation of promoter regions may contribute to tumorigenesis by silencing tumour suppressor genes, while hypomethylation of oncogene promoters may result in overexpression of the oncogene. Hypomethylation may also increase the rate of mutation.

While epidemiological data linking air pollution to a higher risk of cancer death, experimental evidence confirming its carcinogenic impact is limited. Some experimental investigations indicate that PM-bound metals are to blame for genotoxicity. Nevertheless, determining the genotoxic effects of individual metals found in PM is challenging. Because of their ability to produce ROS through Fenton chemistry, zinc, copper, vanadium, iron, and nickel may be more significant than other metals. While soluble organic chemicals seem to be substantially linked to PM-induced cancer, evidence from epidemiological and experimental investigations are insufficient to substantiate this.

Conclusions, Controversies, and Future Directions

In vitro testing has clearly made significant advances to the study of PM-related health consequences, giving evidence for biological plausibility and comprehension of some of the basic cellular mechanisms implicated in disease processes. We know that PM may provoke inflammatory reactions, change DNA, and cause irreversible cellular damage that leads to cell death. These responses might occur directly on cells or as a result of secondary reactions produced by particles, such as inflammatory processes. Cell activation through surface receptors is an example of the first kind of mechanism (Bonner et al., 1998), while the second production of ROS is an example of PM-induced responses. The latter is at the heart of oxidative stress: the new work theory for explaining PM-related biology and poor health effects. Despite significant progress, there are still uncertainties about sampling methods, the exposure-dose relationship in ambient environments, more precise interpolation of cellular study results to humans, the role of individual versus mixtures of PM components, the effects of particle properties on specific adverse health outcomes, and the relationship between PM and the more unique combination of polluted air.

The sample medium, which might be filters or water. Since air quality regulations are concerned with particle size and mass fractions, the bulk of sample systems have been built for gravimetric analysis rather than particle recovery. There are currently no defined procedures for collecting PM for testing purposes. Techniques should be created to handle difficulties such as PM mass and sample size and composition representativeness. Remarkably, the biological impacts of PM seem to be similar regardless of the techniques employed to collect such pollutant. Nevertheless, comprehending the uncertainties imposed by variations in collecting techniques and adjusting analyses for sample discrepancies employed by diverse research groups are required for evaluating and balancing the relative role of PM components in documented biological effects.

The topic of how PM concentrations utilized in in vitro research transferred into actual human open community exposures remains unsolved. Cellular effects have been seen in experimental experiments at doses as low as 2.5 g/cm2, while optimum acute effects have consistently been reported around 40 g/cm2. While some may think this to be a very high concentration that is unlikely to be relevant for open broad human population exposures, data from modelling and animal research provide a different perspective on this subject. Particles deposit on hot regions in airway bifurcations, producing deposition enhancement factors of 100, according to modelling efforts (Balashazy et al., 2003) and animal experiments (Brody et al., 1981). With a human airway surface area of 2471 cm2, this means that a person would need to breathe in around 1000 mg of PM to achieve a concentration of 40 g/cm2 at hot spots on airway bifurcations (Mercer et al., 1994). Breathing such large PM masses (about 1000 mg) is not out of the question, given that a human could do so at a rate of 30 L/min of air with average PM concentrations of 50 g/m3. According to fixed site monitoring data from certain big metropolitan areas, such as Mexico City, where the 98th percentile of 24-h means may surpass 120 g/m3, urban people may be often exposed to high PM levels. Moreover, this threshold corresponds to the newly issued WHO 24-hour PM10 mean air quality standard (SEMARNAT2007, 2007). While additional study is required in this area, present data suggests that experimentally relevant amounts are not too dissimilar to PM concentrations seen in metropolitan environments impacting open human populations.

Connecting experimental findings with health consequences associated to PM exposure in urban populations needs a great deal more research. The consequences of proinflammatory cells on human health disorders such as asthma, chronic bronchitis, and even certain cardiovascular illnesses are possible. Yet, the role of necrosis/apoptosis in unfavourable health consequences is not well known. Impairment of defense/repair processes might explain results such as reduced lung development, synergisms with infectious agents aggravating acute respiratory unfavourable situations, or increased susceptibility to viral pathogens. Thus far, research into the impacts of different PM components has concentrated on identifying individual PM toxics that cause distinct biological effects. Traditional experimental paradigms are based on one-to-one toxicological assessments of toxicant effects. Metals and organics have been found as significant contributors to oxidative stress via ROS production. Yet, there is evidence that cellular responses are the consequence of interactions across PM components, which produce in complex patterns of cellular responses. Generating and understanding data from PM-related mixes is a mental and methodological challenge. In this regard, significant new research employing concentrated ambient particles (CAPs) has been done (Ghio and Huang, 2004). The use of CAPs enables for the investigation of PM component interactions as well as interactions between PM and pollutant gases. Moreover, recent experimental work employs statistical approaches typically employed by epidemiologists to attempt to untangle the cellular effects of the different PM components (Becker et al., 2005a; Veranth et al., 2006; Rosas Perez et al., 2007). Several studies were able to connect PM components or PM emitted by particular emission sources to distinct patterns of cellular responses.

While they are statistical approximations, they give hints for developing a hypothesis linking PM composition with distinct cellular responses that may result in unique undesirable human health effects. This is an example of how toxicological evidence feeds into and supplements epidemiological research' findings.

CHAPTER - 11

HEALTH RISK ASSESSMENT AND MANAGEMENT

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Air pollution is a serious worldwide environmental issue, especially in metropolitan areas where pollution levels are high. Depending on the kind of pollutants present in the atmosphere, it is accountable for a range of environmental and health hazards. Carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (Vocs), lead (Pb), and airborne particulate matter are the six most prevalent (or "criteria") pollutants for which national ambient air quality guidelines are established in many countries (PM). PM, a complex combination of physically and chemically varied chemicals that exist as solid particles or liquid droplets of varying sizes, has received considerable study in recent decades. The aerodynamic dimensions of airborne particles are used to classify them.

PM generally varies from 0.001 to 100 m, but particular attention is presently being devoted to the respirable fraction, that is, PM2.5, since such particles may harm human health. Because of their tiny sizes and aerodynamic properties, these particles may go deep into the lung and get confined for an extended length of time, if not permanently. In human lung models, both experimentally determined regional deposition data and mathematically derived deposition fraction demonstrated that fine particles, UFPs, and nanomaterial deposit more efficiently in the tracheobronchial and alveolar regions, whereas coarse fractions of respirable suspended PM (SPM) are more likely to be confined to the laryngeal and nasal regions (Heyder et al., 1986; Martonen et al., 2002). Since the rates of particle clearance procedures in the lower respiratory tract are substantially slower (Miller, 1999), smaller particles carrying hazardous substances have a higher potential to harm human health than bigger particles with equal chemical makeup. Some particles may enter the circulation and ultimately wind up in other key organs such as the liver, kidney, heart, and brain, where comparable inflammatory responses might be predicted (Takenaka et al., 2001; Oberdorster et al., 2004).

A number of other recent investigations have reached the same result These epidemiological studies quantify the numerous health hazards that the exposed population faces. Nevertheless, they are often too time-consuming and expensive, and they may be muddled by a variety of other factors such as the presence of other gaseous pollutants, age, gender, weather, demography, and socioeconomic position. As an alternative metric, a straightforward quantitative approach to health risk evaluation based on current toxicological data is chosen. depicts the conceptual framework and the four major phases involved in determining the potential health impacts of particle air pollution exposure and, if feasible, mitigating or remediating the issues via effective control techniques. Data collection and review are the first steps in every risk assessment process. There are two techniques to obtaining appropriate data sets in order to meet the final goal of assessing the risks encountered by a specific group. The first strategy is to assess the emission rates of a range of particle pollutants of health concern at the site of release and then use air dispersion modelling to forecast the actual inhaled concentration of an exposed person some distance away. Many air quality models have been created for this purpose, which use mathematical approaches to mimic variations in concentration caused by physical and chemical processes in the atmosphere. The United States Environmental Protection Agency's Support Center for Regulatory Atmospheric Modeling (SCRAM) is part of the Air Quality Modeling Group (AQMG).

The sources of interest must first be identified in the first approach. Particles may come from both natural and anthropogenic (man-made) sources, and they can be expelled directly into the atmosphere (primary particles) or generated by the reactivity of atmospheric gases (secondary particles). Since secondary emissions are caused by primary emissions, controlling particle emissions typically focuses on reducing primary particle emissions. Primary particles from natural sources include biogenic, microbiological, crustal, marine, and volcanic aerosols, while primary anthropogenic sources include combustion processes that burn coal, oil, natural gas, biomass, and other fuels. In general, particles produced by combustion sources are smaller in size within the fine range and so pose a larger health risk. Internal combustion engines of petrol and diesel-powered cars are one of the leading outdoor producers of primary PM2.5. On the other hand, smoking and cooking are two main contributors of indoor PM2.5 concentration. Tucker (2000) calculates the overall emission rate of many indoor and outdoor sources.

After a specific source has been identified, controlled laboratory studies are often conducted to identify their emission variables, as stated by Zhang and Morawska (2002). Gasoline and diesel engines, biomass burning (Hays et al., 2005), environmental tobacco smoke, and incense burning are among the significant combustion sources investigated (Lung and Hu, 2003). The United States Environmental Protection Agency's SPECIATE library provides PM speciated profiles from a variety of sources. Overall, this strategy contributes to a better knowledge of the quantity and kind of particles released by a single source. Yet, since humans are often exposed to a mix of particle pollutants from a variety of sources, the second strategy may be preferable. Apart from monitoring ambient air, indoor air quality has recently received a lot of attention because it is well known that most people spend more than 80% of their time indoors especially in occupational settings where people are exposed to high levels of particulates.

To summarise, the first stage directly or indirectly analyses or estimates the concentration of hazardous particle pollutants to which humans are exposed in either outdoor or indoor situations. Nevertheless, since people are not always exposed to the same atmosphere throughout the day, additional parameters such as the amplitude, frequency, duration, and mode of exposure (inhalation, ingestion, and skin absorption) must also be addressed. Inhalation is the primary route through which airborne contaminants come into contact with individuals. This kind of exposure evaluation is considered in the second phase of the risk assessment process. After identifying the suitable exposure pathways and situations, the inhalation dose may be computed as the quantity of contaminant in contact with the body at an exchange boundary per unit weight per unit time.

The third phase is toxicity evaluation, which calculates the link between the amount of exposure and the increased likelihood and/or severity of adverse consequences. Toxicity profiles for selected carcinogens, noncarcinogenic chemicals, and radioisotopes can be obtained from the Risk

Assessment Information System (RAIS), which compiles all relevant information presented in the United States Environmental Protection Agency's Integrated Risk Information System (IRIS) and the Health Effects Assessment Summary Tables (HEAST), as well as other published works. The last stage, risk characterization, uses all of the other procedures to quantify the risk of chemical exposure for an exposed person.

A TSI Model 3034 Scanning Mobility Particle Sizer was utilised for particle size and monitoring in this study (SMPS; TSI Incorporated, MN, USA). The SMPS monitors the number of particles in the range of 10-500 nm via 54 channels at a flow rate of 1 L min-1 and estimates the total particle number concentration up to 107 cm-3. The sampling duration was set to 3 minutes, resulting in one scan per sample. This study looked at five commonly used cooking methods and their associations with indoor particulate air pollution in the kitchen: steaming (cooking over boiling water), boiling (cooking in a liquid heated to, or past, its boiling point), pan-frying (frying in a small amount of oil), stir-frying (frying quickly in a small amount of oil over high heat while stirring continuously), and deep-frying (frying by immersing in hot oil). In all cases, a pack (150 g) of plain tofu (soybean curd) purchased locally was cut into 10 circular pieces measuring 3.0 cm (diameter) by 1.5 cm thickness and cooked in the same Chinese wok generating a steady heat of 3.0 kW for a sufficient amount of time to obtain a representative number of samples per cooking method each Time the testing conditions for several cooking techniques. The wok was carefully cleaned between cooking experiments. After the particle levels recovered to their baseline level, the next experiment began; this level refers to the particle number concentration of all sizes being within 10% of the background concentration recorded in the kitchen when there was no cooking.

The mean number concentrations show that gas cooking released a significant quantity of particles. During gas cooking, total counts increased 2-24-fold over the background level, notably during oil-based cooking techniques such as pan-frying, mash, and deep-frying, compared to water-based cooking methods such as steaming and boiling. This trend in particle number concentrations may be ascribed to high-temperature heating of frying oil (fatty acids), which produced more particles than boiling water. Moreover, water has a far higher boiling point than maize oil, which has a boiling point of 245°C; hence, at high temperatures in the kitchen, water droplets are more likely to exist in the gaseous form than in the particulate phase, while less volatile oil droplets prefer to stay as particles.

Deep-frying created the most particles, as shown in the table, followed by stir-frying, pan-frying, boiling, and lastly steaming. The much higher number concentration of particles during deep-frying compared to stir-frying and pan-frying can be attributed to the larger quantity of cooking oil used and not the temperature of the oil (Siegmann and Sattler, 1996) because the temperature was stabilised at 190°C before tofu was added, which was then kept at room temperature to reduce the drop in temperature. The same quantity of oil was used in both stir-frying and pan-frying. As a consequence, the particle counts produced by these two approaches were equal. Nevertheless, the number concentration was found to be somewhat lower during stir-frying because the turbulence induced by continuous stirring action may have caused a more efficient dispersion of particles. Also, the temperature of the oil was seen to drop by 5°C during churning, which might explain.

reduce the concentration. In contrast to the findings of Siegmann and Sattler (1996), who discovered that the peak diameter increased with temperature, the modal thickness did not drop in the case of stir-frying despite the lower temperature. This might be due to the various methodologies used in the two investigations; in the other trial, there was no stirring process. When the wok was covered during steaming, particles may have been held within and so released fewer particle counts than boiling.

This correlation between particle counts and cooking techniques seems to be consistent with prior findings in the literature. For example, Li et al. (1993) reported that the total count mean concentrations of particles in the size range of 17-886 nm during the cooking of vegetable soup (considered to be boiling according to this study), scrambling eggs (stir-frying), and frying chicken (deep-frying) were 1.9 105, 3.3 105, and 4.0 105 cm-3, respectively. Dennekamp et al. (2001) measured a peak UFP concentration of 1.1 105 cm-3 in boiling water, 1.4 105 cm-3 in stir-fried veggies, and 5.9 105 cm-3 in pan-fried bacon.

This research also found that cooking with oil (stir-frying, pan-frying, and deep-frying) released more hazardous submicron-sized particles than cooking with water (steaming and boiling). During oil-based cooking, nanoparticles accounted for 69% (stirfrying) to 90% (deep-frying) of all particles, compared to 55% during steaming and 62% during boiling. Water-based cooking, on the other hand, created more ultrafine and accumulation mode particles, owing to the greater humidity in the kitchen. The water vapour produced when boiling water might have condensed on pre-existing nanoparticles, forming bigger particles in the ultrafine and accumulation modes. This is shown by the change in the modal diameter during steaming and boiling trials. Three spectra are given, depicting the size distribution at the beginning, middle, and conclusion of the cooking experiment. The peak can be seen shifting to the right as the cooking occurred. The quantity of nanoparticles dropped while the ultrafine and accumulating modes rose. Throughout the three distinct frying procedures, no such tendency was found.

The size distributions of the number concentration were clearly bimodal during steaming and boiling, with a dominating peak at 10 nm, a lesser peak at 70-80 nm, and a local minimum at 25 nm. Pan-frying had a similar characteristic, however the mode in the ultrafine range was less noticeable. Despite the fact that the bulk of the cooking events included frying, this is consistent with the findings of Wallace et al. (2004). From 24 cooking sessions, the later investigation indicated a bimodal distribution with a peak at or below 10 nm and a second peak at 60 nm with an intervening minimum at 16 nm.

Nevertheless, stir-frying and deep-frying procedures produced more complicated and jagged profiles with at least three peaks, despite the fact that all modal diameters were in the ultrafine and nano ranges. Where fj and f are the deposition fractions of particles of size j and all particles ranging from 10 to 500 nm, respectively. Cj (cm-3) and C (cm-3) are the number concentrations of particles of size j and all particles between 10 and 500 nm, respectively. Nj (cm-3) and N (cm-3) denote the number of particles of size j and all particles from 10 to 500 nm that may be deposited in the lung per cm3 of air breathed in. The calculations above assume that all particles in cooking emissions are inhaled.

A significant quantity of deposited particles may lead to particle overload, which can cause acute inflammation and hinder alveolar macrophage-mediated lung clearance. This vicious cycle is likely to persist as additional particles collect due to delayed particle clearance, potentially leading to lung tumour after a series of pulmonary episodes (Oberdorster et al., 1995). Von Klot et al. (2005) discovered that at a rate ratio of 1.026 per 104 cm-3, cardiac readmissions increased with the number concentration. As a result, exposure to cooking emissions is hazardous to one's health and should be avoided to the greatest extent feasible. Cooking should be done in a well-ventilated area if possible, to reduce the number concentration and the potential health effects.

Extraction and Chemical Analyses

Following the techniques outlined by Karthikeyan et al., the quartz filters were removed and tested for PAHs (2006). In brief, the filters were processed for 20 minutes at 150 W microwave irradiation with 20 mL of 1:1 (v/v) reagent grade acetone:hexane in an MLS1200 MEGA closed vessel microwave digestion system (Milestone srl, Sorisole (BG), Italy). The extracts were concentrated to 3 mL using a rotary evaporator, then to near dryness with a moderate stream of nitrogen at 20°C and redissolved in 1 mL of the extraction solvent for PAHs analysis. The evaporative loss of low-molecular-weight PAHs was reduced by properly drying them at moderate temperatures with a tiny constant flow of nitrogen.

Individual PAHs were identified by comparing retention durations (chromatographic column) and mass spectra (mass detector) of PAHs in aerosol samples to those of PAH standards (full scan mode). Prior to sample analysis, the GC-MS was calibrated with three different doses (200-, 500-, and 1000-times dilution) of the 16 PAHs (Supleco, 100 ppm for Phe, Ant, Pyr, BaA, Chr, BkF, BaP, Ind; 100 mg / l for Flu, Flt, BbF, DBA, Bpe; 1000 ppm for Nap and Acy; 2000 ppm for Ace). Moreover, PAH recoveries were evaluated by processing four sets of SRM 1649a urban dust (National Institute of Standards and Technology, MD, USA) in the same way as the samples and comparing them to certified values. The retention durations, main ions (m/z), regression coefficient for calibration, and recoveries. 5. One of our recent articles has information on the limit of detection [LOD, 0.3 10-3 ppm (BaP) to 8.81 10-3 ppm (Flt)] and the limit of quantification [LOQ, 0.59 10-3 ppm (BaP) to 17.63 10-3 ppm (Flt)].

PAHs in PM2.5: 0.25%), next the Chinese stall (201.8 g m-3, 141.0 ng m-3, 0.07%), and finally the Indian stall (186.9 g m-3, 37.9 ng m-3, 0.02%). Although PM2.5 levels rose by factors of 8.3, 6.9, and 6.4, respectively, PAH levels increased by factors of 14.3, 61.6, and 3.8 when compared to background levels at the Chinese, Malay, and Indian vendors. The variation in particle pollution levels across the three food booths may be explained by the varied cooking operations that occurred in each stall. It has been shown that the kind of fuel (Oanh et al., 1999), oil (Wu et al., 1998), food (McDonald et al., 2003), and cooking techniques (Lee et al., 2001) used during the operation are the key variables contributing to the quantity and type of pollutants emitted. Cooking emissions dispersion inside each stall is also expected to impact particle concentrations. The three food booths, however, have similar layouts and are naturally ventilated with almost comparable air change rates. As a result, the variations in PM2.5 and PAH concentrations between the stalls are assumed to be independent of dispersion circumstances. Moreover, as previously stated, all three booths utilise solely LPG as fuel and vegetable oil for cooking. The three ethnic food vendors prepared a range of vegetables, meat, and fish in varying quantities. As a result, the factors addressed here are the volume of food cooked, the length of time spent cooking, and the cooking techniques employed.

The chefs calculated the amount of food prepared and the overall amount of time spent cooking on each day. Deep-frying (frying by immersing in hot oil), stir-frying (frying quickly in a small amount of oil at high heat while stirring continuously), panfrying (frying in a small amount of oil), boiling (cooking in a hot liquid kept just below its boiling point), and steaming were all used to prepare the food (to cook over boiling water). The most contaminated booth was discovered to be the Malay stall. Nevertheless, this vendor prepared less food on a daily basis than the other two (30 kg compared to 45 kg at the Chinese stall and 40 kg at the Indian stand). The time spent cooking was around 10 hours, whereas it was approximately 8 hours at the Chinese stand and approximately 20 hours at the Indian stall; this calculation was based on the number of petrol burners utilised for cooking. The greater mass concentrations of PM2.5 and PAHs at the Malay booth compared to the other two stalls seem to be related to the cooking technique utilised. Deep-frying is the primary cooking technique at the Malay stall, which serves a variety of deep-fried delicacies such as fried bread, banana cakes, bananas, and curry puffs in addition to rice and side dishes. The most prevalent cooking technique at the Chinese booth, on the other hand, was stir-frying, in which the ingredients were either raw or partly cooked by pan-frying, and the procedure itself took just a few minutes. The cooking technique at the Indian booth is boiling, since Indian curry is a popular meal at the stall, and this recipe needs boiling until the components are soft.

approach, which might be owing to the greater temperature maintained while cooking and the bigger volume of oil used in deep-frying. Acrylamide, a cancer-causing chemical created when starchy foods such as potatoes are fried at high temperatures, has been shown to rise in concentration with temperature (McDonald et al., 2003). When high-temperature cooking is employed, both PM2.5 and airborne PAHs may follow the same trajectory. This hypothesis is confirmed by greater mass concentrations of PM2.5 and PAHs, as well as a larger proportion of PAHs in PM2.5, measured at the Chinese booth than at the Indian stand, since the stir-frying cooking technique includes a higher temperature and more oil than boiling. Also, the bigger amount of food prepared at the Chinese stall may contribute to the increased level of particle pollution. The findings achieved here are congruent with what was discovered in the controlled studies.

Health Risk Assessment

To generate a more accurate estimation of the health hazards connected with petrol cooking at the various booths, the mass concentrations of PM2.5 and PAHs were compared with current regulatory criteria designed to safeguard the public or employees' health with an acceptable safety margin. The USEPA established the PM2.5 National Ambient Air Quality Standard (NAAQS) in 1997 at 15 g m-3 for the annual standard (three-year average of the annual arithmetic mean concentrations) and 65 g m-3 for the 24 h standard (three-year average of the 98th percentile of 24 h concentrations); other PM2.5 standards exist for different countries. Nevertheless, analogous indoor air quality standards or recommendations for PM2.5 do not yet exist. The PM2.5 levels recorded at the food booths over a 24-hour period were 115.6, 137.4, and 108.1 g m-3 at the

Chinese, Malay, and Indian stalls, respectively, which are much higher than the 24 h NAAQS and hence cause worry for health. According to the USEPA, a one in a million probability of developing an extra human cancer during a 70-year lifespan is deemed tolerable or insignificant, but a lifetime risk of one in a thousand or above is considered dangerous and requires immediate treatment.

In the Chinese, Malay, and Indian shops, the ELCR total was calculated to be 4.86 10-6, 1.81 10-5, and 8.73 10-7, respectively. The first two figures are more than the allowed limit for ELCR, which is 10-6. Our estimates indicate that the chefs and other personnel in the Chinese and Malay restaurants, as well as the customers who frequent the food booths, are exposed to an extremely high concentration of tiny particles containing carcinogenic PAHs. As a result, human exposure to cooking emissions at food booths is a major health hazard. The same findings were made in real-world kitchens. The Malay booth, where the majority of the food was deep-fried, had the greatest concentration of PM2.5 and PAHs, followed by the Chinese (stir-frying) and Indian stalls (boiling). The amount of food prepared may also contribute to an increase in particle pollution in kitchens. The equivalent mass concentrations of BaP for all three food stalls were computed and found to be higher above the European limit (0.7-1.3 ng m-3). According to the health risk assessment, occupational exposure to cooking emissions in the three commercial kitchens is a major health hazard. Appropriate preventive measures should thus be implemented to decrease cooking emissions and/or reduce human exposure to such emissions, particularly when significant amounts of food are prepared using deep-frying or stir-frying [19], [20].

Estimation of Health Impacts due to PM10 in Major Indian Cities

Air pollution causes a variety of health concerns. Inhaled air contaminants have major consequences for human health, damaging the lungs and respiratory system. Air pollution affects various individuals in different ways. Those who are poor, undernourished, very young or very elderly, or who have prior respiratory illness or other health issues are particularly vulnerable. The effects of air pollution on health are quite complicated, and toxins may have synergistic effects when humans are exposed to many contaminants in the environment. PM10 are the suspended particulates having a diameter of less than 10 mm and are small enough to enter the respiratory tract and pulmonary system of human being. Anthropogenic sources of PM10 include fuel combustion in industries and homes, traffic/road dust, construction activities, solid waste disposal, waste incinerators, refuse/biomass burning, and so on. Naturally occurring processes, such as dust storms, volcanic eruptions, forest fires, soil erosion, and so on, also contribute significantly to the particulate pollution. A lot of money is spent on treating illnesses caused by air pollution. The United States spends more than $6 billion on asthma, whereas the United Kingdom spends roughly $1.8 billion on asthma health care and missed work days. Annual direct and indirect health expenditures connected with asthma in Australia are almost US$460 million.

The average monthly cost of treating a kid in Malaysia is US$ 15.56. India also spends a lot of money on asthma treatment, which is mostly caused by particle pollution. While asthma cannot be cured, the number of asthma cases may be reduced by lowering the amount of particle content in the air (Anon, 2004). PM10 may have a variety of chemical compositions and health effects. Due of the concentration of human activity in and around metropolitan areas, the levels are often much greater than in rural regions. Identifying probable sources and population groups vulnerable to PM10 exposure would be a requirement for their control/mitigation. The sections that follow explain the air quality criteria for PM10, observed levels of PM10 in key Indian cities, and estimated instances of death and morbidity in these cities, which are classed as metro, industrial, quickly growing (e.g., information technology focused), and other.

Standards for PM10 and its Status in Major Indian Cities

Monitoring for PM10 began in the early 1990s at 30 monitoring stations administered by the National Biochemical Engineering Research Institute (NEERI), and was subsequently expanded to additional sites under the CPCB's National Air Monitoring Plan in the late 1990s. PM10 statistics from the CPCB (www.cpcb.nic.in) have been evaluated, and the yearly mean levels of PM10 in major Indian cities' residential zones for 2001, 2002, and 20036, along with the exceedance factors (EFs). The ratio of pollutant concentration to the Standard for that pollutant is defined as EF. The pollution level is classified as critical (EF: >1.5), high (EF: 1.0-1.5), moderate (EF: 0.5-1.0), or low (EF: 0.5-1.0). According to the data, PM10 levels surpassed the CPCB threshold of 60 g/m3 in all cities between 2001 and 2003, with Ahmedabad and Kanpur having the highest concentrations. In these cities, the WHO recommendation of 40 g/m3 was also exceeded by a ratio of 2-5. PM10 concentrations were found to be decreasing in Ahmedabad, Bhopal, Kanpur, Kochi, Indore, and Surat, but rising in Bangalore, Delhi, Jaipur, and Pune. Such fluctuations cannot be explained definitively and are due to a variety of unorganized/unidentified local area source activities. The investigation of numerous pollution sources in each city, as well as the prevalent weather circumstances across time, should explain these variances.

It is not just the ambient air quality in cities that is raising worry, but also the interior air quality in rural and urban locations. According to studies, contaminant levels in interior spaces might sometimes be greater than those observed outside. Pollution in the interior environment may raise the risk of sickness because (1) the pollutants are discharged close to the building inhabitants and (2) poor ventilation can increase thier levels by not moving indoor air away from the building.

In underdeveloped nations, a significant section of the population relies on biomass to meet their energy needs. Wood, charcoal, agricultural waste, and animal waste are examples. Cooking and heating using open fires is widespread in both rural and urban homes. Children and women are more likely to be impacted in such families since they spend more time inside. PM is the primary pollutant of concern, and it is considered to be the leading cause of mortality in rural India. Many of the fatalities in children are caused by acute respiratory infections; others are caused by cardiovascular disorders, lung cancer, and chronic respiratory diseases in adults. Household use of coal and biomass may have a negative impact on indoor air quality if emissions are excessive and ventilation is inadequate.

Smith (2000) examined the health impacts of indoor air pollution with a focus on India. He reviewed available epidemiological research and assessed the entire burden of illness (mortality and morbidity) attributed to the use of solid fuels in adult women and young children, who are both at high risk due to their home duties. He roughly calculated that the usage of biomass fuels in these demographic groups causes 400-550 thousand premature deaths per year.

Estimation of Health Impacts due to PM10

Since it comprises a vast spectrum of hazardous compounds, PM produces the most numerous and significant consequences on human health of any air pollutant, and PM10 may be regarded a valid indication of the impact of atmospheric pollution. The major constituents of PM are water-soluble inorganic ions [NH4 +, NO3 -, SO4 2-, Na+, K+, Mg2+, Cl- (sum of the concentrations of NH4 +, NO3 - and SO4 2- represents the secondary inorganic particle fraction)], elemental and organic carbon (EC and OC), and trace elements (Al, As, Ba, Br, Ca, Ce, Cd, Cu, Fe, Ga, K, La, Mg, Mn, Mo, Nd, Ni, Pb, Rh, Sb, Se, Tl, V, Y). The chemical composition of PM10 is determined by the sources of origin and the activities that influence the sample location. In Switzerland, research was done at three sites representing suburban areas, kerbside locations, and rural areas.

Methodologies

Epidemiology research is essential to investigate possible links between various environmental variables and human illnesses. They are distinguished by statistical analysis of data obtained on individuals' health status, pollutant exposures, and any confounding variables. Such studies often provide evidence of possible causal relationships between pollutant exposures and observed or reported health effects. In general, epidemiological data become increasingly significant as the risk attributed to air pollution decreases and the length of exposure necessary to generate effects increases. These studies have been especially helpful in detecting the acute consequences of high short-term pollution exposures. Adverse consequences may include alterations in pulmonary function, asthmatic episodes, and an increase in mortality.

The health implications of air pollution, namely PM10 (known as the leading source of health issues in metropolitan areas), have been explored. The concentrations of PM10 in key Indian cities in 2001, 2002, and 2003 are shown. According to data analysis, PM10 levels in most cities surpass 2-3 times the permitted limit of 60 g/m3. Moreover, PM10-related mortality and morbidity have been quantified and reported for 14 important Indian cities. Based on 2001 PM10 concentration levels, Delhi is determined to be the most afflicted, while Bangalore is shown to be the least affected it terms of health effects. The uncertainty involved with estimating health risks underlines that PM10 levels fluctuate significantly over time, resulting in huge discrepancies in estimates.

a. Epidemiology research to determine the dose-response relationship between pollution levels and health effect in Indian circumstances.
b. Determination of typical pollutant exposure concentration values in both ambient and indoor air in urban and rural locations.
c. Epidemiological studies to assess the effect of PM10 management techniques on health. The development of cost-effective abatement policies is heavily reliant on: (1) a complete understanding of the source apportionment of airborne PM; (2) an understanding of how new emission controls will affect primary pollutant emissions and thus airborne concentrations; and (3) a reliable source-receptor relationship for secondary pollutants, which also form PM (Harrison et al., 2008). Maenhaut (2008) stressed the need of ongoing and expanded worldwide aerosol chemical composition monitoring and study.

d. Additionally, Pope and Dockery (2006), after reviewing a number of health impact studies, emphasised the need for research to understand (1) the most vulnerable group of people; (2) the effects of PM exposure on infant mortality and various birth outcomes, such as foetal growth, premature birth, intra-uterine deaths, and birth defects; (3) the effect of ambient PM on lung cancer risk; and (4) the role of various PM characteristics and constituents, and what they mean.

Health Risk Assessment and Management for Air Toxics in Indian Environment

A series of catastrophes throughout the globe, including those at Flixborough (1974), Seveso (1976), Bhopal (1984), Pasadena (1989), and others, have raised concerns about the possible dangers and risks associated with chemical process industries (CPIs; Kim et al., 1995; Khan and Abbasi, 1998). Such industrial mishaps may result in significant injuries and/or catastrophic damage to infrastructures both within and outside the workplace. Apart from the inadvertent discharge of very dangerous substances, the continual emission of toxic pollutants from big industrial facilities and other anthropogenic activities may also have a negative impact on human health and the environment. There are several standards, actions, laws, and regulations in place to limit and regulate pollution. They help in the preparation and implementation of emergency response plans in the event of a disaster. Among those employed for regulatory purposes are the Manufacturing, Storage, and Import of Hazardous Chemicals (MSIHC) Regulations, 1989 (later revised in 1994 and 1999), Hazardous Waste (Management and Handling) Rules, 1989 (later amended in 1997 and 1999), and Public Indemnity Insurance (PLI) Act, 1991. Despite several regulations and legislation, dangerous substances are nevertheless handled in an unsafe and ecologically harmful way. this is evident in the many catastrophic incidents that happened in the last several decades, such as those in Bhopal (1984), Panipat (1993), Bombay (1995), and Visakhapatnam (1997).

As a consequence of rising knowledge of the magnitude of tragedy that may follow actions employing such chemicals, there is also considerable anxiety about the inadvertent discharge of hazardous compounds. The creation of adequate regulatory measures necessitates an acceptable trade-off between economic value and possible damage associated with such activities, emphasising the need of quantitative risk assessment (QRA) of unintentional discharges of hazardous compounds into the environment. In scientific terms, risk is defined as a mixture of two factors: (i) the likelihood of an unfavourable event occurring and (ii) the consequences of the adverse event occurring.

More specifically, risk is a mix of projected frequency and the outcome of a single or series of incidents. This type of risk is associated with an emergency situation that includes an acute hazard (i.e., the potential for an injury or damage to occur as a result of such an instantaneous or short-duration exposure) caused by an episodic event (i.e., an unplanned event of limited duration that is usually associated with a disaster).

as a result of an accident). Yet, there is another sort of risk known as chronic risk, which is caused by long-term exposure to harmful substances over months, years, or decades, resulting in chronic health issues. Chronic exposure risks emerge from activities linked with the production and consumption of food, energy, industrial and consumer products, as well as trash generated by everyday life. This chapter provides a detailed description of the following research, which include both acute and chronic dangers.

CHAPTER - 12

CONCEPT OF ACUTE RISK

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A vast number of chemical catastrophes in the past demonstrate that the unintentional discharge of dangerous compounds is a serious issue. This is particularly true when the emission results in the creation of a big cloud very instantly. In many cases, such a cloud will have a higher density than the surrounding air. Because of the ground-hugging nature of thick toxic clouds, a huge portion of the population is exposed to hazardous substance exposure. As a result, developing adequate models for heavy gas dispersion or negatively floating cloud is critical. In this connection, it is worth noting that suitable heavy gas models (IIT Heavy Gas Model I and II) have been created and validated against field testing. Mohan et al. (1994, 1995) present in detail the foundations and use of the IITD Heavy Gas Model for dense gas dispersion of airborne dangerous compounds for assessing individual and societal risk, susceptible zones, and user-oriented nomograms.

Model Formulation and Validation

IT Heavy Gas Model is a numerical box model in which the governing equations account for key physical phenomena such as gravitational slumping, air entrainment, cloud heating, and so on (Singh et al., 1991; Mohan et al., 1995). The numerical solution of the equations assesses the cloud parameters at each time step, namely the radius (length in the case of continuous release), height, density, temperature, and quantity of entrained air. Model validation has been prioritised by comparing their performance to relevant field trial data (Thorney Island, Burro Series, and Maplin Sand Trials) as well as other models. An excellent performance of the model has been established based on statistical assessment. The IIT Heavy Gas6 Model's performance is comparable to that of the model with the best performance among 11-14 other models established in different nations.

Estimation of Vulnerable Zones

The IIT Heavy Gas model distinguishes itself by determining various zones on the city map in terms of concentration isopleths corresponding to IDLH (immediately dangerous to life and health), STEL (short-term exposure limit), and TLV (threshold limit value) for a given release and meteorological situation. As a result, regions of possible effect may be quickly recognised, and necessary emergency preparation procedures can be implemented in the event of an industrial catastrophe. Concentration isopleths are supplied here for a 65-tonne chlorine storage facility at Shriram Foods and Fertilizers Industries (SFFI) in Delhi. The location and amount of storage are purely for demonstration purposes as they existed in the past. Nevertheless, they do not support the current circumstance. The climatic scenario used for isopleth charting relates to stable air conditions with low wind speed and reflects the circumstance in which the maximum value of IDLH distance is reached. We plotted the isopleths using North-Westerly wind direction based on climatological data on wind frequencies. As a result, the regions of possible influence are located in the site's south-easterly direction.

User-Oriented Results

Based on this model, some user-oriented findings have been presented that might be utilised by a layperson for emergency control and management without having to work on the sophisticated mathematical simulation technique on a computer machine. The aforementioned paper (Singh et al., 1991) shows a nomogram for different chlorine storage volumes under various meteorological conditions that may exist throughout the year, which are indicated by scenario numbers. The word "nomogram" refers to a graph from which safe distances are calculated as a result of the unintentional discharge of various amounts of a dangerous chemical under various meteorological situations that may exist in any given year. By knowing the time of the accident, cloud cover, and noticeable wind impacts in the surrounding area, the atmospheric conditions at the time of the accident may be readily associated with the scenario number.

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Chronic Risk

Possible health hazards associated with carcinogens in the Indian atmosphere for cadmium, chromium, and nickel have been assessed and reported by writers in the is included: Gurjar et al. (1996) and Gurjar and Mohan (1996). (2003a). Chemical pollutants have grown in the atmosphere as a consequence of urbanisation, industrialisation, increasing automotive traffic, and agricultural usage of fertilisers and pesticides. India has established several industries to fulfil its own needs as well as for export. By exposure to harmful particles in the air environment, the expansion of metallurgical architecture, heavy engineering, and diverse chemical industries in India has produced new and complicated potential health concerns for both employees and the society at large. As a result, quantitative analysis of human health hazards has grown in importance as a way of not only assessing the amount of risk associated with chemical pollutants, but also identifying management techniques that may decrease these risks to an acceptable level. This research evaluates the individual and social dangers posed by three carcinogenic metals found in the atmospheres of several Indian states, namely cadmium (Cd), chromium (Cr), and nickel (Ni).

d with a risk level of 10-5. Cancer typically occurs one in every four people; hence, in a group of 100,000 people, 25,000 are likely to get a tumour over their lives. If the same 100,000 people breathed air polluted with 5 10-3 mg/m3 (ambient air intermediate guideline concentration) cadmium every day for the rest of their lives, just one extra person (i.e., 25,001) would get cancer.

Gujarat and Himachal Pradesh. Before to 1950, the Union Territory of Chandigarh was a traditional farming terrain, hence the high ambient concentration of chromium at this site is somewhat remarkable. It may be worthwhile to investigate if industrial firms, notably those manufacturing cement only a few miles east of Chandigarh, are leaking hexavalent chromium into the atmosphere. Cement manufacturing facilities are significant potential sources of chromium in the atmosphere. At the time when these data were collected for the Ministry of Environment and Forests (MOEF), the Government of India, there was a massive cement factory about 3 kilometres east of Chandigarh (UT) (GOI). A huge number of small-scale companies involved in the fabrication of fasteners and electroplating may also be contributing to the high chromium concentration in Chandigarh's environment. Prolonged inhalation of high doses of hexavalent chromium (30-40 years) increases the probability of developing lung cancer in humans.

Nickel

Residents in Chandigarh (Union Territory) seem to have the greatest individual risk estimate related to nickel exposure, followed by those in Uttar Pradesh, Bihar, Haryana, and Punjab It may be worth investigating whether the high levels of nickel in the ambient air and the increased risk estimates of lung and nasal cancers attributable to nickel exposure in some northern Indian states (Union Territory of Chandigarh, Uttar Pradesh, Bihar, Haryana, and Punjab) are linked to coal combustion. Coal combustion is one of the primary causes of nickel emission into the atmosphere (ATSDR, 1993).

The estimated cancer risk associated with chromium pollution of ambient air seems to be larger than that associated with nickel contamination. Cigarette smoking considerably increases cadmium intake. The daily intake of cadmium may range from 1 to 6 mg/day depending on the type of cigarette and the number of cigarettes smoked (Pandya, 1978). When 10% of cadmium consumption is believed to be absorbed in the lungs, it may provide 3-19 times greater danger to the smoker than the highest risk in Uttar Pradesh state (Gurjar and Mohan, 1996). The societal risk for chromium is greatest in Bihar, and for nickel and cadmium in Uttar Pradesh. This is logical given that, in terms of overall population, Uttar Pradesh and Bihar are the top two states among the 14 displayed in this table. Societal risk and population (total and density) are major considerations in determining future industrial expansion and location. Because to different limitations in both available data and the models used to compute potency factors and effective concentrations, developing accurate risk estimations is difficult (Fiksel, 1985). Yet, this form of average risk level calculation might be valuable for planning reasons. The approach used here is useful for evaluating carcinogenic risk due to carcinogens present in the environment. Yet, there are some constraints. For example, the assumption of average population implies a homogenous population distribution with equal background variables such as sensitive populations, age, and sex. These constraints restrict the scope of this strategy and should be considered when utilising it in planning and judgement tasks [21].

Integrated Risk Analysis Using Both Acute and Chronic Risk: Case Studies

The usual practise of studying different categories of risk in isolation from one another may result in incorrect results. This is due to the fact that, in real-world scenarios, an individual or group may confront various combinations of environmental dangers presented by the surroundings. In light of this, an integrated method for environmental risk analysis (ERA) has been developed in order to clearly examine and create a complete instrument, especially for hazardous hazards, that is generally representative of real-life risk circumstances.

To begin, individual risk factors (IRF) and geosocietal risk factors (GSRF) for two Indian enterprises that may provide an acute danger owing to an unintentional release of chlorine into the atmosphere have been evaluated. Moreover, background risk factors (BRF) were calculated by translating the likelihood of additional cancer cases into death per year owing to the presence of carcinogenic toxic substances in the environment. The cumulative individual risk factors (CIRF) and cumulative geosocietal risk factors (CGSRF) have been estimated as the totality of the hazards caused by acute and chronic toxic exposures, respectively, for individual and society risk. As a result, opinions on the possible applications of risk analysis vary. Most experts and policymakers, for example, agree that risk analysis is a good tool for informing choices, but they dispute over how skewed risk assessments are and whether they should be permitted to affect consumer policies to safeguard health and the environment. It is frequently agreed that it should be used first to target and address the most serious risks to health and the environment, to achieve risk reduction in more cost-effective and flexible ways that minimise overall economic impacts, and to ensure that risk reduction achieved through regulations is worthwhile. Quantitative approaches, critics argue, cannot analyse extremely long-term or freshly identified dangers. They also argue that quantitative cost-benefit studies overestimate environmental and health advantages, exaggerate costs, and concentrate on relatively broad but individually minor costs and hazards rather than substantially bigger costs and dangers to smaller (and sometimes more vulnerable) populations.

They are difficult to comprehend or quantify. Another issue is that the models greatly simplify what occurs in nature. This is why, given the same set of data, multiple models may provide widely disparate answers, depending on the underlying premises and assumptions employed in model construction (Smith et al., 2000). This makes selecting one model and rejecting the others tough. Another disadvantage of QRA is the need for accident and equipment failure data, which becomes scarcer as plants grow safer. Yet, tendencies might be seen. One typical cause of failure is "correlated failure," which occurs when it is expected that backing up the piece of equipment would boost safety. An explosion would destroy two generators positioned adjacent to each other in an example of "external" linked failure. Internal linked failure occurs when environmental causes weaken the Teflon seals of two identical pumps and a pressure surge destroys both of them. As the trend towards automated technology continues, human error is becoming a more major component in failures. Additionally, the quality of risk analysis is determined by the data's sufficiency and the method's validity. There are few data and methodologies that are problematic for environmental dangers and most health and ecological repercussions. As a result, there is a rising impression that risk analysis has done a poor job of forecasting the environmental and health consequences of many new technologies.

Air Quality Management: Techniques and Policy Aspects

Throughout the past 200 years, tremendous environmental difficulties and irreversible mass extinctions have occurred on Earth, mostly due to human activities. As a result of this significant damage, some estimates indicate that not only are more than 100 species becoming extinct every day, but our natural resources that sustain life on the planet—air, water, and soil—are becoming polluted or depleted on an alarming scale, in tandem with exponentially increasing human population growth (Desjardins, 2001). This means that as the chances of continued degradation and depletion of natural resources increase as a result of population growth, natural resources on the planet, such as clean water, clean air, and clean soil, will become a luxury, and resources for future generations' survival will become scarce.

Humans are selfish, and they see nature as a renewable resource. It is equally disconcerting to realise how far the illusion of having solved the manufacturing issue has progressed. If we continue to ignore the distinction between income and capital for nature, mistakenly treating nature as an income item rather than a capital item, we will reach a point where the negative effects of environmental damage will be irreversible, and we will continue to destroy our planet and possibly even cause our own extinction. To put a stop to these debates, industrialised nations have started to reverse health consequences and decrease the expense of environmental pollution in metropolitan areas during the previous half-century. As a result, Environmental Economics has arisen as a discipline of economics to deal with environmental concerns using traditional Neoclassical Economics methodologies and to conduct theoretical and empirical investigations of the economic impacts of national or municipal environmental policies all over the globe. As a consequence, concerns like as the costs and benefits of pollution, alternative environmental policies to address air pollution, water quality, dangerous compounds, solid waste, and global warming have emerged as critical issues for analysts to address.

The health impacts of environmental pollution, particularly air pollution, have been the focus of numerous epidemiological research for risk assessment concerns and of Environmental Economics for policy decisionmaking processes in the past 50 years. With increased community awareness of human health and air quality problems, a considerable amount of epidemiological research demonstrating the negative health consequences of air pollution and focused on the detrimental effects of air pollutants on public health has arisen. Based on these scientific results, which show that differing degrees of air pollution endanger human health and the environment, environmental regulatory bodies in many nations have imposed rigorous air quality standards (BTRE, 2005). These studies have also demonstrated that these exposures may have a greater impact on human health than previously thought (WHO, 1999). Long-term exposure to low levels of particulate matter in the air is nevertheless connected with mortality and other chronic consequences such as higher incidence of bronchitis and impaired lung function. There are many phases of health impacts, according to the World Health Organization (2000a). The health consequences of air pollution on the affected population go from moderate or subtle health effects (subclinical effects) to the most severe health effects (premature mortality). In the meantime, altered pulmonary functions, limited activity/reduced performance, doctor visits, emergency room visits, and hospitalisation may all be viewed as distinct forms of severity of health impacts in the afflicted population.

Numerous epidemiological studies have shown that these pollutants endanger human health. They observed that, particularly in the long run, urban air pollution might cause bronchitis, respiratory illnesses, lung cancer, and premature mortality. Their findings also revealed that carcinogenic compounds in the tiniest air particles and carcinogenic gases, such as benzene and benzopyrene, might be potential causes of cancer. the principal contaminants found in the air pollution mix. Changes in the concentrations of these pollutants in urban air, such as nitrogen dioxide or particulate matter, became a source of worry for worldwide air pollution standards and several organisations, including the European Environment Agency (EEA, 2004). Moreover, policymakers in Western industrialised nations used more systematic ways to calculate the economic consequences of air pollution on human health and to establish efficient environmental solutions that met both social and economic efficiency goals (Ad-hoc Group, 1999). The qualification of environmental-related health consequences and their monetary worth are critical in policy actions.

Since environmental pollution is an irrefutable truth, and the economic costs of pollution on human health are very large, we must find urgent solutions to a number of concerns, such as: What are the core duties of economics and economists? What actions should economics take to decrease or eliminate pollution? What is the origin of the valuation procedures that we employ?

What is the most often used environmental management analysis method? Finally, why must we choose the strong environmental and social policy among alternatives?

The primary goal of this research is to analyse some of these concerns, beginning with Neoclassical Environmental Economics and progressing to an interdisciplinary approach. There is an obvious need for this research since there aren't enough economic studies to assess the magnitude of pollution on Earth. As a result, this research attempts to look at the whole picture from the perspectives of air pollution, economics, and policy.

Since it is an irrefutable reality that environmental pollution occurs and that the economic costs of pollution on human health are extremely substantial, we must find urgent solutions to a number of concerns, such as: What are the core duties of economics and economists? What should economics do to prevent or eliminate pollution? What is the source of these valuation procedures that we employ. The primary goal of this research is to analyse some of these concerns, beginning with a Neoclassical Environmental Economics viewpoint and progressing to an interdisciplinary approach. The necessity for this research is obvious, since there are not enough economic studies to assess the magnitude of pollution on Earth. As a result, this research is an effort to look at the whole picture from the perspectives of air pollution, economics, and policy.

evaluates CBA within the context of Neoclassical Environmental Economics to illustrate how individual preferences for environmental decision making and the effect of air pollution on health may be measured and compared. CBA was chosen because it is the most well-known approach employed by policymakers, as well as one of the most contentious. This section will examine the rationale of CBA, its structure, and its conceptual underpinning in depth. Investigates non-neoclassical approaches to environmental economics, such as Austrian Economics, Environmental Economics, and Ecological Economics. This part is critical after studying Neoclassical Environmental Economics and its analysis methodologies since we need to replace current assumptions with more realistic ones. We must do so not just to solve the challenges of

Neoclassical Environment Economics, but also to improve our economic knowledge of environmental concerns. outlines our results and gives some recommendations to decision makers.

Theoretical Basis of Neoclassical Environmental Economics

Economics has a critical role in determining modern-day activities by enforcing standards for what is and is not economic. Thus far, no other factors have more effect on the behaviour of people, organisations, and governments than economic ones. The ideas of natural capitalism and environmental finance, which are two sub-branches of Environmental Economics concerned with resource conservation in production and the value of human biodiversity, were and continue to be heavily influenced by Neoclassical Environmental Economics. With growing clout, Neoclassical Environmental Economics has pushed to the forefront of public concern about environmental challenges. Within Neoclassical Environmental Economics, there are three major economic methods.

Utilitarianism

Utilitarianism is a nineteenth-century ideology that varies from ethical theories that base the rightness or wrongness of an act on the agent's purpose. According to the utilitarian, the correct deed may be done with a wrong motivation. Among the well-known utilitarians, Jeremy Bentham and John Stuart Mill should be highlighted. Utilitarians generally believe that well-being should be the goal of people, and they use happiness to make decisions regarding activities (Mill, 1965). Since the ultimate goal is to increase collective utility or welfare, they think utility must be something that can be readily defined or assessed. On one level, the judgement as to whether one condition of circumstances is better than another is based only on the total of personal utilities. Inequalities in distribution, for example, are undesirable because they reduce the total of utilities. Increased productivity is beneficial if it promotes overall satisfaction. Utilitarians think that low levels of pleasure are just as important as high levels of pleasure, and that economic pleasure is just as important as noneconomic joy. If utility is to be evaluated in their idealised universe, it should be feasible to identify how many units each person enjoys and how many more the same individual enjoys in one condition compared to another.

CHAPTER - 13

AN OVERVIEW ON UTILITARIANISM

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Utilitarianism is an early nineteenth-century ideology that varies from ethical theories that base the rightness or wrongness of an act on the agent's purpose. According to utilitarianism, the right deed may be done with a wrong purpose. Jeremy Bentham and John Stuart Mill are two well-known utilitarians. Utilitarians generally think that happiness ought to serve as an individual's goal, and they use happiness to make decisions regarding activities (Mill, 1965). Since the ultimate goal is to increase collective utility or welfare, they think utility must be readily quantifiable or assessed. On one level, the judgement whether one condition of circumstances is better than another is based only on the total of personal utilities. Inequalities in distribution, for example, are negative because they reduce the total of utilities. Greater output is beneficial if it boosts overall satisfaction. Utilitarians think that low levels of pleasure are just as important as high levels of pleasure, and that the economic is just as important as the noneconomic. If utility is to be evaluated in their idealised universe, it should be feasible to know how many units each person enjoys and the additional units the same individual enjoys in one scenario vs another.

Individuals are also said to follow their own self-interests since they are the greatest judges of their own well-being or pleasure. As a result, there should be no interference with their private decisions. In contrast, utilitarians say that governments may combine social and private utility for public policy objectives in order to maximise aggregate utility. As a result, utilitarianism has been and continues to be immensely important in economics, public policy, and government legislation, as well as playing a key role in environmental policy (Desjardins, 2001). According to Bonner (1995), "since many feel that utilitarianism provided reasons why one is better than another, it enabled policy debate". Since the total of individual pleasure should be the goal of public policy, income redistribution will be good if total utility, which is the sum of all individual utilities, rises (Bonner, 1995). As a result, there is no foundation for condemning the presence of great disparity since the fundamental purpose is to fulfil as many individual desires as possible.

A variety of objections have been presented against utilitarian reasoning. The most crucial are utility measurement, individual welfare comparison, and aggregation of interpersonal utility information. In reality, measuring, comparing, and combining individual utilities is difficult, if not impossible in certain circumstances. How can decisions be measured, scaled, or traced back to their origins? How can we compare people's levels of satisfaction? How should individual wellbeing be aggregated to produce societal utility? How can we measure things like pleasure, happiness, desire, and so on?

These are critical problems that even utilitarians cannot easily address (Bonner, 1995). To begin with, we cannot simply assume that all wants or pleasures are essentially equal. One obstacle for critics is the measuring issue. Utilitarians substitute something measurable in monetary terms for the good, which is seen as a fundamental error. Utilitarians assess and analyse the health repercussions of pollution management policies by utilising measurable variables as proxy for health, such as life expectancy, infant mortality, and per capita health-care spending; however, these variables cannot cover all elements of the worth of life. To address this issue, utilitarians believe that in the marketplace, everything has a price in order to be exchangeable, while there's nothing that does not have a price. This, according to opponents, is precisely what happens when environmental regulations are submitted to CBA. Regulators use diverse economic parameters connected with health as proxies for environmental policy since they cannot evaluate the worth of health itself. Then they presume that weighing the cost of health against the cost of eradicating the source of pollution is sufficient to make policy judgements. Even basic noneconomic qualities such as beauty, cleanliness, and health can only persist if they can be shown to be "economic" and subject to CBA.

Another difficulty is from the nature of practical judgements. Since utilitarians believe that no act is ever good or bad in and of itself, they do not consider the repercussions of a specific act. Opponents argue that this technique is insufficient and fails to account for some ethical considerations. Each civilization has its own set of rights and wrongs, and behaviours might vary depending on the importance that society puts on specific things. In conclusion, utilitarianism is one of most powerful methods that impact public policy choices on environmental challenges, but it is also one of the most contentious. This is why environmental disputes are increasingly framed in utilitarian terms.

Neoclassical Efficiency

The Neoclassical Efficiency Theory, which may also be considered as an extension of utilitarianism, is the second important approach to environmental policy decision-making. What precisely is Neoclassical Efficiency Theory? How does it relate to the process of making environmental decisions? This section will address these concerns. The three major assumptions of Neoclassical Economics are (1) the availability of perfect knowledge, (2) the transitivity of other options, and (3) the existence of positive marginal utility/product if and only if nonzero inputs exist. The primary rationale for the perfect information assumption is to allow for reasonable decisions (Choudhury, 1995). Consumers, according to neoclassical theorists, are rational beings who behave rationally and make rational consumption decisions in order to maximise their own self-interests and individual rational choices. As a result, the ultimate objective of consumption for a rational consumer is utility maximisation, which is bound by income and pricing (Hanley and Spash, 1993). As a result, the same consumer will always.

According to Neoclassicists, the fundamental cause of social inefficiency is that social costs associated with external consequences, like as the health repercussions of air pollution, are not integrated into the cost of manufacturing the polluting commodity or its market price. According to this viewpoint, the primary answer is to raise the total value of production to the level that would be achieved if pollution costs were included in its price. In such conditions, resources would be efficiently reallocated. When production and consumption are organised such that all air pollution costs are correctly represented in product pricing within competitive marketplaces, the market is said to be Pareto efficient, which means that society cannot be made better off on the whole (Cordato, 2004).

The greatest criticism has been levelled towards Neoclassical Theory at this stage. One such objection comes from environmental ethics, which says that if an economic system is one in which more people receive more of what they are willing to pay for, why should we prioritise individual preferences? How can we know if our particular tastes are good or bad for us in the long run? Why should the fulfilment of individual preferences be the purpose of public policy, especially when it comes to environmental issues According to critics, these are the key challenges that Neoclassical economics must solve quickly in order to address today's environmental issues.

Some opponents also contend that Monetarist analysis is important in many modern environmental policy challenges. CBA, in particular, is the primary public policy tool used to make environmental choices and shape environmental policies at the national and international levels. But, when the concept of economic efficiency becomes so popular among policymakers, we cannot simply accept the standards of satisfying human desires. According to Sagoff (1990), most economic analysis is based on a severe misunderstanding of d sires or preferences versus beliefs and values.Therefore, Neoclassical economics only deals with desires and preferences since they are what are represented in monetary terms in an economic market, but it overlooks beliefs and values because they are not accountable.

1. Pigou (1956) created a formal welfare theory that could be applied to economic situations.
2. policy. His research aimed to shed light on the subject of whether fully competitive markets result in optimal resource allocation. As a result, Pigou demonstrated that enterprises'
3. It is possible that marginal cost functions might not adequately represent the social costs of manufacturing.
4. Individual demand curves may not fully represent the societal gains from consumption. Consequently, Pigou (1956) investigated the differences between. There are differences between private and social gains, as well as private and social expenses.
5. These divergences were dubbed spillover, spill-over effects, and third-party impacts by him.
6. They are often used to justify government acts. The expenses that a company considers in Profit maximization choices are paid by the corporation as private expenses. But there are societal costs.
7. Pollution, for example, is not borne by the enterprise; consequently, there is a difference between private and societal costs at the margin. As a consequence, a free market will produce. Manufacture of an excessive number of items with marginal social costs that exceed.

Their private marginal cost. When this occurs, governments step in to fix the situation. the consequences. Classical Economic Theory employed the idea of before Neoclassical Theory. welfare. Although traditional economics saw wellbeing as increasing production, Neoclassical economists saw wellbeing as more than just an increase in production. with the assistance of the marginal utility notion (Colander, 1989; Roll, 1992). Thus, by differentiating between economic theory and policy, Welfare Economics became an essential component. of the Neoclassical

Economics policy decision-making process. When it comes to economic Theory grew more formal, and welfare economics became a distinct subject. Welfare Economics, like earlier methods, has been criticised. As Its conceptual foundation is based on Classical and Neoclassical Economics. The literature on Welfare Economics, however, adopts a different conceptual framework. Choudhury (1995) views it as more of a reformulation of underlying Methodology based on the Neoclassical school of thought. The Neoclassical welfare approach may be seen as providing a new notion, such as externalities; yet, it does not significantly undermine the end goal, which is to maximise collective utility or welfare.

Economic Valuation

According to Neoclassical Environmental Economics, natural resources supply products and services for which there are no obvious markets or markets that are highly imperfect. Since there is no market for environmental commodities and products, unlike man-made goods and products, their monetary worth to individuals cannot be easily recognised. The primary hurdles for Neoclassical economics in dealing with this issue are to first determine the effects of pollution and then assess the value of these environmental changes. Many direct and indirect valuation strategies have been developed to quantify these changes. Because the economic approach to valuing environmental challenges is based on people's preferences in their environment, the underlying principle for measuring the intensity of people's WTP for an environmental benefit or, conversely, their willingness to accept compensation for environmental degradation (Pearce and Howarth, 2000) is the same as for man-made products. It is expected that if these quantities can be quantified, economic valuation will enable environmental effects to be evaluated on the same basis as the financial costs and benefits of various environmental pollution management scenarios. As a result, it will be possible to assess the societal costs and benefits of various environmental challenges in connection to public policy.

WTP Approach

The WTP method determines how much we are ready to spend to minimise risk, which is the avoidance of a statistical mortality or disease.eviewed the health cost components in their study and stated that WTP includes individually borne costs (such as individually borne treatment costs, individually borne loss of production due to illness, individually borne avertive expenditures, and individually borne intangible costs due to averting behaviour) but does not consider collectively borne costs (such as collectively borne treatment costs, collectively borne loss of production due to illness, collectively borne avertive expenditures indicates that the WTP method includes individual material expenses and indirect costs but excludes material costs that are paid collectively, such as insurance payments.

The WTP technique is pretty well established in order to prevent a statistically early death discovered that in 1996, health expenses attributable to traffic-related air pollution were over 27 billion euros throughout Austria, France, and Switzerland (a total of 74 million people). This equates to around 1.7% of GDP and an annual average of 360 euros per capita. Premature mortality is the most common cause of death in all three nations, accounting for almost 70% of total expenses. Lvovsky et al. (2000) assessed the composition of health expenses attributable to air pollution by cause and found that premature deaths accounted for around 40% of the health costs, with different diseases accounting for the remaining 10%. Chronic bronchitis (25%) and acute respiratory symptoms (25%) are the two most significant contributions to morbidity-related economic expenses.

Human Capital Approach

Human Capital is a partial technique that considers the current worth of future labour income. It is calculated by assessing medical expenditures as well as lost revenue, output, or consumption as a result of premature death and sickness, however it solely considers material costs. This is usually accomplished by assessing the present value of a person's potential future production as measured by the discounted expected stream of earnings. This approach essentially estimates and evaluates the years lost owing to mortality. Further costs are added to this basis, such as monetary estimates of lost quality of life, the value of nonmarket production, and resource expenses such as medical and hospital bills (BTRE, 2005). The literature on life valuing using the Human Capital concept is extensively developed.

Economics of Abatement

Neoclassical economics proposed a series of assumptions based on the Paretian premise's "optimality" criterion. The social optimum, often known as "economic efficiency," requires both distribution and exchange efficiency and can be attained only in perfect competition when price equals marginal cost. Yet, if there are externalities, such as pollution, the market fails since price does not match marginal cost. For example, in the presence of negative spillover, the societal costs of health outweigh the private costs of health, implying that the market result in the instance of pollution is no longer efficient. To preserve "economic efficiency," pollution costs must be internalised; that is, they must be considered by the polluter. Yet, for things like as air or water, the property right structure is unclear when it comes to determining the compensation method, and an externality problem develops [22], [23].

In the existence of negative externalities, the potential cost of a market activity would exceed the private cost of the activity, resulting in an inefficient market outcome. When the market result is inefficient and the market tends to over-supply a product, a Pigovian tax equal to the negative externality is imposed on a market activity to repair the market failure. In the face of a positive externality, the provision of Pigovian subsidies would stimulate market activity since the market would tend to under-supply the product. Since markets do not internalise pollution and failure, tradable licences were invented by neoclassical economists, making government intervention necessary. As a result, it is the responsibility of governments to absorb costs and restore efficiency. Governments have two political tools for internalising costs: (i) centralised taxes based on the Pigovian tax and (ii) decentralised tradable permits based on the Coase Theorem.

To do this, governments should levy a tax on each unit produced and restore the economy to its previous level of efficiency. Despite the fact that it is based on a basic premise and is one of the "classic" methods of dealing with market failure, the "knowledge issue" might be critical for the use of Pigovian tax in practise. The Pigovian tax does not operate when there is asymmetric information or when there is insufficient information. Moreover, taxes cannot be imposed globally in the event of overseas activity. Pigou himself admitted that interfering with individual choices might be challenging for the state (Pigou, 1954). Yet, economists argue that imposing a Pigovian tax is preferable than no tax at all.

ii. Permits that may be traded: The transferable permits concept (or the formation of a market for "pollution rights") has been proposed as an alternative to Pigovian taxes from the late 1970s in the United States and since the 1980s in other industrialised countries. The government provides the precise number of licences required to create the targeted emission level in order to grant or sell the right to pollute for a certain fee to its holder. They can be bought and sold on the market because they are freely transferable, and they function as property rights even internationally. A tradable permit system establishes a permitted total amount of pollution and distributes permits among enterprises. Companies that maintain their emissions below their authorised level may sell their extra permits to other enterprises or use them to mitigate excess emissions in other aspects of their operations.

CBA, which derives from Neoclassical Economic Theory, is used as an analytical tool to give a way of systematically comparing the value of results with the value of resources necessary to achieve the desired outcomes. After the conception of some of the formal principles that are regarded the cornerstone of CBA by Alfred Marshall, it was originally formed in 1936 to improve the environmental judgement process in the United States (Hanley and Spash, 1993). Since then, policymakers in many nations have used CBA to assess the costs and benefits of air pollution mitigation strategies. In order to do so, they assigned monetary values to health benefits and marginal harm estimates and compiled a complete, although mostly qualitative, analysis of the health consequences of particles, dioxide, and ozone. Moreover, these policymakers did quantitative meta-analysis on mortality from time series studies, hospital admissions, especially coughs in patients with persistent respiratory symptoms.

In general, the essential assumptions for conducting a CBA are to identify sources and quantify NOx and volatile organic compounds (VOCs) emissions, compute processing dispersion and ozone concentration, estimate yield loss using exposure-response models, and value yield loss. Yet, when using this strategy, policymakers confront several obstacles in dealing with long-term repercussions such as irreversibility, insufficient information, risk, and uncertainty. The primary reason for these difficulties is because civilization has changed and gotten more complicated, and the nature of environmental concerns has become far more complex than we can fathom.

Rationality of CBA

CBA's logic originates from the legitimacy of public policy since it is a technical instrument designed to help in the decision-making process. It is a well-known truth that welfare measures in public policy serve two core purposes: efficiency and equality. When a policy optimises the overall net benefits accessible to society, it is considered to be efficient. A policy, on the other hand, is independent of who gets the net benefits. In other words, equity is concerned with how the pie is divided among members of society rather than the "size of the pie" (Hanley and Spash, 1993).

In the United States, for example, CBAs of air pollution rules by the USEPA have showed considerable net benefits from lowering fine particles. Section IV of the 1990 Clean Air Act, which lowered SO2 emissions from power plants, costs just $2 billion per year but generates more than $60 billion in health benefits.

Equity and CBA: Under the Neoclassical Economic perspective, CBA is not expressly created as a tool for analysing equity. Nonetheless, there is a widespread consensus that CBA should also promote the equitable allocation of costs and gains throughout society. If a researcher has to gather data (on age, gender, income, race, geographic area, and time) to perform a CBA study, he or she should be able to try to identify how benefits are allocated. As a result, it is not difficult for an analyst to evaluate the imbalances between benefits and expenses for the most disadvantaged groups of the population. In practise, however, equality is not considered as the primary issue of the CBA since efficiency improvement is the primary goal.

Critics of the air pollution control programme argue that, while efficiency seeks aggregate gains, equity seeks to determine whether costs and benefits are systematically reallocated in ways that discriminate against citizens least able to protect themselves, or in favour of citizens who already have an advantage. As a result, certain possible Pareto improvements may be deemed undesirable, regardless of the size of the gap between gains and losses (Hanley and Spash, 1993). After considering both fairness and efficiency for the same project, the final choice will be able to incorporate if easily identifiable subsets of the population, such as the poor or the elderly, systematically inhabit the most polluted locations. If they do, the social acceptability of safeguarding vulnerable persons may take precedence over providing the highest net benefits. These issues have grown in prominence as it has become clear that market forces paired with environmental legislation may have unintended and unfavourable repercussions. Environmental justice is a term used to describe such issues.

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Most Neoclassical economists strongly endorse the application of the prospective Pareto improvement criteria in air pollution control policies since it helps assess if a project or policy on air pollution control increases the welfare of society as a whole. They say that since there are so many individuals and so many projects and programmes, it is inevitable that certain policies will help many people while others will harm them. As a result, policy choices should only seek the greatest net advantages for the majority Over time and with a big number of choices and people, everyone will begin to gain since resource allocation decisions attempt to achieve the most benefit at the lowest cost.

Technical Conceptual Framework for CBA

Net present value of the project: In the CBA air pollution application, the analyst must calculate the net present value of the project over time and compare the most recent costs and benefits to costs and benefits that often occur in other time periods. Although if this increases the complexity of the analysis and makes it difficult to directly compare costs or benefits now with costs or benefits 10 years from now, it is critical for an analyst to have a deeper understanding of the project's content. Since comparisons need a consistent measure, CBA employs a technique known as discounting to quantify all future costs and benefits in present value equivalents. This is accomplished by discounting expenses and benefits for each future time period and adding them together to arrive at a current value. In general, the longer the time horizon and the greater the discount rate, the less influence each particular year has on the overall net benefits.

Yet, the net present value technique is regarded as one of CBA's most basic flaws. This is because this computation approach is focused on current generation choices and ignores future generation decisions. It is for this reason that costs that occur far into the future are given little weight in traditional CBA. In actuality, although we should consider discounting to describe all future costs and benefits in their present value equivalent for current generations, we should also address intertemporal fairness concerns and include in the costs to future generations.

ii. Input value selection: According to Neoclassical Environmental economics, the choice of input values approach is a superior strategy than the net present value method since the former ultimately dictates the analysis's outcomes. Parameter values related with costs and benefits indicate options in this strategy. Future rates of economic growth, the concession rate, and future population rates are among the parameters available. Coping with uncertainty: Uncertainty is regarded as the most significant barrier to CBA and has a direct detrimental influence on cost and benefit estimates. As a result, it is critical that a CBA incorporate sensitivity and scenario analysis to address the issue of uncertainty. These two analyses should be carried out to demonstrate how the findings vary as a consequence of alternative analytical choices and variations in the unknown amounts of important costs and benefits.

iv. Selecting between alternatives: The key to CBA is choosing between a defined set of options. For example, there might be various options for reducing air pollution. For example, establishing an air pollution levy, changing the transportation system, updating sewage systems, or moving to new manufacturing methods may all compete to reduce air pollution. Both the preventative and remediation choices may be further subdivided into alternatives depending on the technology available to achieve each aim. Choosing amongst options is therefore a challenging undertaking while conducting a CBA, and a decision maker must exercise extreme caution in order to pick the most rational one.

Coping with uncertainty: Uncertainty is regarded as the most significant barrier to CBA and has a direct detrimental influence on the calculation of costs and benefits. As a result, it is critical that a CBA incorporate sensitivity and scenario analysis to address the issue of uncertainty. These two studies should be carried out to demonstrate how the findings alter with various analytical options and variations in the unknown amounts of major costs and benefits. iv. Selecting between alternatives: The key to CBA is to choose between a defined set of options. For example, there may be various options for reducing air pollution. Imposing an air pollution tax, for example, altering transportation networks, updating sewage systems, or moving to new manufacturing methods may compete in terms of lowering air pollution. Both the preventative and remediation possibilities may be further subdivided into alternatives depending on the technology available to fulfil each aim. Choosing between options is therefore a challenging process while conducting a CBA, and the decision maker must exercise extreme caution in order to pick the most rational one.

Alternative Approaches to the Neoclassical Environmental Economic View

Argue vehemently against the Neoclassical efficiency method and enumerate their concerns. Austrian School economics reject mainstream Neoclassical ideas because they are theoretically flawed and do not represent reality. The Austrians argue that, although these false assumptions have led to policy prescriptions over the previous 200 years, they are entirely nonoperational now (Cordato, 2001). Several Austrian economists have criticised the notion of externalities, which is one of the most essential principles in Neoclassical Environmental Economics. The following are the Austrians' main issues with the Neoclassical Environmental Economics conceptual framework: (i) efficiency is a matter of individual goal-seeking, not value maximisation; (ii) costs are subjective, therefore societal costs and value systems do not exist as quantitative or even theoretical ideas; and (iii) Pareto optimality is useless as a real-world efficiency standard.

CHAPTER - 14

GREEN ECONOMICS

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Green Economics is a popular viewpoint in which an economic system is seen as a component of the environment. E. F. Schumacher, Murray Bookchin, Lewis Mumford, Miriam Kennet, Rachel Carson, Brian Tokar, Robert Costanza, David Korten, Buckminster Fuller, Herman Daly, Paul Hawken, Amory Lovins, Jane Jacobs, and Robin Hanson are the primary contributors to Green Economic Theory. Green economists, like Austrian economists, say that their viewpoint is fundamentally distinct from that of Neoclassical economics.

Whereas Neoclassical Economics is the dominant school of thought in contemporary economics, Green Economics shares larger ecological and social concerns, including a rejection of capitalism itself. As a result, Green Economics extends beyond the more specific issues of Neoclassical Environmental Economics, Resources Economics, and Sustainable Development, all of which are considered subcategories of Green Economics. To build an understanding of ecological challenges and ecological economic options, many green scientists have been greatly inspired by Marxian perspectives. Their significant distinctions and philosophies will now be studied. Green Economics shares larger ecological and social issues, including a rejection of capitalism, even if Neoclassical Economics still makes up the majority of contemporary economics today. Because of this, Green Economics, which is a subset of Neoclassical Ecological Economics, Resource Economics, and Sustainable Development, extends beyond their more limited concerns. Marxist ideas have had a significant impact on many green economists as they have developed an awareness of ecological challenges and ecological economic options. We'll now look at their primary distinctions and guiding concepts.

Ecological Economics

A relatively new area of economics, ecological economic theory, examines the interconnectedness and coevolution of human economies and natural ecosystems. Robert Get more, Herman Daly, Nicholas Georgescu-Roegen, David Harvey, and John Bellamy Foster are the leading experts in this discipline. It has certain characteristics with Green Economics, but it also departs from that theory in that it has a unique goal that integrates economic reasoning with an understanding of biology and physics. In other words, it combines scientific and social science facts. As a result, it aims to increase human wellbeing via economic growth that is founded on a balance between ecological concerns and human needs. Similar to this, the key distinctions, tenets, and solutions of ecological economics will be carefully investigated in order to comprehend the fundamental conceptual framework.

The primary distinction between neoclassical environmental economics and ecological economics is that: Neoclassical Environmental Economics is criticised by Ecological Economics, along with other schools and methodologies, for being myopic and near to environmental truths and for thinking that the environment is a part of the human economy. Ecological economists contend that Neoclassicists are unjust for implying that economic pollution and its detrimental effects on human health can be readily remedied by giving compensations. Yet ecological economists contend that the Ecological Economic Theory, which integrates nature and human economics, provides more effective answers to the issues. For them, human economy is by definition encompassed inside ecological economics, while the ecology side deals with the energy and matter interactions of life and the Planet.

Ecological economists share the Green Economic Theory's conviction that limitless economic expansion is neither feasible nor desirable because of the finite nature of our resources. It is said that even if nature is finite, we don't need to destroy it in order to gain more since it already gives us everything we need. When considering the cost to filter water and other similar services, some estimates place the price of environmental services at over 33 trillion dollars. Sustainable development is advocated by ecological economists as opposed to economic growth. Moreover, they think that the best way to raise the quality of life for people all around the globe is via sustainable development. They contend that whereas sustainable development focuses on raising quality of life, quantitative economic growth emphasises per capita rate, which may have negative impacts on the environment and even on wider social well-being.

An interdisciplinary strategy would be: However, ecological economists tend to recognise that a lot of what is crucial for human health cannot be fully understood from an exclusively economic perspective, and they recommend a multidisciplinary strategy to deal with complicated problems like pollution. They contend that in order to resolve difficulties, a platform should be formed using both social and natural disciplines. Costanza and Perrings (1990) provide an example of how to reconcile what we already know about the uncertainties of environmental preservation with what we also know about the challenges of more direct forms of social control such as taxation as restrictions or outright bans. They assessed a flexible assurance bonding system in order to provide more efficient, less invasive, and generally more beneficial stimuli to safeguard and/or control environmental usage.

Developers would be required to post this bond, which would have a value equivalent to the greatest anticipated environmental harm that may result from the planned activity. After the company established that the harm would not or could not occur, the bond would be maintained in an interest-bearing account and given to the developer along with a portion of the interest. The bond would be used to help pay for repairs or recompense individuals hurt if the disaster did materialise. But the developer wouldn't be compelled to make any future payments. They also contend that teaching consumers about the need of living in harmony with environment is a better method to achieve a sustainable ecological and social system. This will stop governmental interference and let consumers and producers to behave in the ecological economy's best interests.

In order to illustrate their main distinctions from Traditional Environmental Economics as well as their disparities with one another, this paper discusses three very different perspectives on environmental issues, including Austrian Economics, Green Economics, and Ecological Economics. They all strongly disagree with the neoclassical environmental economics assumptions, however, and they all have various criticisms for this prevalent viewpoint. The Austrians often see human conflict and disruption of inter- and intrapersonal plan development and implementation as the efficiency issue. Pigouvian Environmental Economics, on the other hand, considers pollution issues largely in terms of resource allocation. The utmost efficiency, on the other hand, is attained by self-sufficiency and the ideal size of operation, according to green economists.

Lastly, efficiency in the context of ecological economics refers to safeguarding the ecological and social system. It is further shown that the Austrians' property rights approach to policy analysis differs from the Neoclassical viewpoint in that the social function of private property is to settle interpersonal disputes and permit the peaceful pursuit and realisation of goals. Yet, the property rights question takes on a new meaning in the arguments made by green economists who reject capitalism and advocate for socialism. Even if they are guided by materialistic beliefs, some green economists have started to examine more holistic and internally consistent features.

Economics is a very new field," according to Colander, "but a very strong weapon." Even though the history of economics as a distinct subject does not go back further than 1500 AD (and the amount of economic literature only increased significantly in Western Europe between 1500 and 1750 and a body of economic knowledge only began to evolve during the period from 1776 to 1876 with an increasing interest in the discipline of political economy), Economics plays a crucial role in determining how the modern world operates by imposing standards of what constitutes success. There is no excuse for us not to comprehend the significance of economics in the context of environmental pollution if there is no other set of criteria that has a larger influence on the behaviour of people, groups, and governments than economic criteria. We must apply economics' practical solutions for environmental issues before it is too late because of how strongly it influences economic decision-making and economic education (IEEP, 2005).

Neoclassical Economics was born at a very amazing time. Modern microeconomic theory first emerged, in particular, during the latter three decades of the nineteenth century. Importantly, Classical Economics was influenced by the development of a new set of analytical techniques, including marginal analysis, to become Neoclassical Economics. The introduction of marginal analysis was noteworthy because it marked the beginning of a discernible rise in the use of mathematics to economic analysis. Neoclassical economic analysis still has a significant influence on decisions about consumption, production, and policy. As an example, CBA is the primary public policy approach used in making environmental choices and forming environmental legislation at any national.

Although having a significant impact on how people, businesses, and governments make choices, neoclassical economics has come under heavy fire from other economic schools, environmentalists, philosophers, and religious groups. Austrian, Green, and Ecological Economics are some of the most well-known opponents of Neoclassical Economics, as was covered in earlier parts. Notwithstanding their disagreements, all of these opponents concur that environmental exploitation is morally wrong. For instance, some academics contend that the premise of methodological individualism is the key to comprehending the Neoclassical school's mental structure from an ethical standpoint.

Sadly, when material components of human wellbeing are prioritised, the moral side of that welfare is often neglected. It is commonly acknowledged that the Neoclassical Economic Order does not prioritise distributive equality, and that as long as rational decisions are made, the economic motivation will suffice to optimise profits, utility, production, and productivity. As a result, the moral objective of distributive equality will ineluctably be less alluring and more expensive to achieve than economic efficiency. In actuality, it is unavoidable that people will encounter a crucial conundrum in this situation. When less equity is selected over greater equity, a questionable decision has been made. Unbalances in the economy will result from the unmet demand and desire for equal distribution. A sacrifice of cost productivity must be made somewhere in the economic system, however, if more equality is selected over less. A trade-off between more distributive equality and worse economic efficiency, however, becomes implausible in markets with companies that maximise their production and consumers that maximise their utility in increasingly more complex economic systems.

Hence, the replacement principle allows for the option between ethical and immoral bundles as a permanent possibility that cannot alter over time with the advancement of information about these choices, as can be shown in the situation of environmental degradation. Since our reliance on nature, the decision between ethical and immoral bundles shouldn't even be a topic for environmental difficulties. The role that people and their economies play in broader natural ecosystems should be acknowledged in economics. The relationships between human economies and their ecosystems have a material and energetic base that defines both social and economic structures and activities. The characteristics of an ecosystem that are common to economies include dynamism, evolution, integrity, stability, and resilience. Human choices must be informed by some idea of the value of their activities and the value of their impacts on ecosystems, in terms of either benefits of usage or costs of abuse, given the size of the possible influence on their own wellbeing via effects on natural systems. For human economies to function rationally within their natural systems, some notion of value is necessary [24].

For the natural system, we have moral and cultural values. As these values are social and not entirely private, they cannot be measured or compared using conventional human preferences based on the supposition that agents are rational. They may also not be represented in the straightforward addition of individual values among social members.

Setting restrictions on human economies would allow for the rise and sustainability of human wellbeing, subject to the resilience of the ecology that supports the economy As a result of the worry that the process of discounting may lead us to policies that unduly prioritise short-term benefit, sustainability has emerged as an extra factor for public policy decision making. But, we must remember that, similar to the consideration of effectiveness, the decision-maker is provided with information by the consideration of sustainability. providing more details, but does not decide by itself. Our primary goal should be to find a method to use the environment more wisely in order to increase human prosperity and wellbeing.

1. Analyze the implications of different moral systems for the sustainability of human wellbeing and highlight any situations where there are obvious inconsistencies between moral systems and sustainability rules. This will help us decrease environmental pollution.

2. Recognize how interdependent economies, people, and natural systems are. This entails being aware of how resilient ecosystems are to changes brought about by humans as well as how resilient economies are to ecological changes.

3. Provide human economies with the opportunity necessary for development and sustainability of human wellbeing, subject to the viability of the environment that supports the economy and the efficacy of proposed solutions.

4. Provide crucial legal and institutional frameworks that help human economies achieve long-term objectives for welfare development.

Controlling air pollution and its effects on health should be a top priority

1. Develop a new technology to better integrate public health and economics perspectives on the burden of illnesses caused by air pollution as a promising development that needs to be supported.

2. Create an integrated framework from various fields and combine the effects of numerous institutions and experts who work in the overlapping fields of public health, the environment, and economics. This can significantly contribute to influencing decision-makers and the general public and can leverage decisions that have a significant positive impact on environmental health.

3. Examine the health effects and early mortality caused by air pollution, particularly in developing nations, since this problem requires increased attention from the worldwide business and philanthropic organisations.

air pollution has a negative effect on people's health. Our health may be significantly impacted by the air we breathe, including conditions like asthma, heart disease, and certain types of cancer. A variety of technologies, tools, and alternatives are available to help clean up our air, and businesses and governments should regard this as a priority—especially for those regions and villages that remain the most polluted and at risk. Tighter air quality standards could be achieved through regulations. The way we think about what to create, how to produce, and for whom to produce ought to be the most significant adjustment we need to make. These are the core issues in economics, and in order to undo the harm we have done to nature, we must first alter the way we think about economics. We must recognise that the Planet belongs to us all, not just a small portion of humanity. We cannot economically expand since we cannot enlarge into an infinite space indefinitely, and we also cannot neglect the needs of future generations.

CHAPTER - 15

ELEMENTS OF AIR QUALITY MANAGEMENT

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Reducing the effects attributable to environmental exposures is a major public health goal with substantial socioeconomic benefits worldwide. Poor air quality (AQ) is one of the main causes of the worldwide environmental burden of illness, according to research. Even in nations with relatively modest concentrations, population health consequences are well documented by science. The effects of climate change, as well as other social pressures like urbanisation, energy production, and waste management, are all impacted by air pollution, which also harms land and aquatic resources, which include those that are directly important economically. As a result, the creation of AQ policy is a dynamic and advanced stage of the environmental management process. Several nations have seen notable advances in AQ during the last few decades, despite the complexity of the process and the need for various diverse but complementary approaches to address the issues.

The first step is an assessment of the most recent health impact data, which establishes the continued need to raise AQ. The examination of the scientific underpinnings of AQ management, which include emission inventories, ambient observations, and atmospheric models, follows this section. These instruments provide a quantitative knowledge of how atmospheric chemistry, meteorology, and natural emissions affect how human-generated emissions are disposed of and ultimately how much exposure is received by the population. They are crucial for recognising AQ issues, monitoring development, and creating successful policies and initiatives to enhance AQ. Determining how models, emissions inventories, and measurements enhance AQ management is therefore a fundamental objective of this chapter, which will also address technical concerns and ambiguities in the use of these instruments. Understanding these problems makes it easier to use these tools successfully and to communicate their findings to AQ managers at all levels of governments and in the business sector. The themes addressed in this chapter are discussed in further detail, and recommendations for AQ management policy measures are provided.

Air Pollution’s Effect on Human Health

In its Global Burden of Disease initiative, the World Health Organization (Cohen et al., 2005) identified ambient air pollution as a top priority. According to this organization's estimates, outdoor particulate matter (PM) air pollution causes 1.2% of all early mortality and 6.4 million (0.5%) years of life lost (YLL). Although while the size of the predicted increased risk may seem to be minor, when the population as a whole is extrapolated, a substantial number of individuals are impacted. There is little evidence supporting a threshold concentration below which air pollution has no detrimental impact on population health or a nonlinear connection between exposure or concentration and health consequences.

Many time-series studies carried out all over the globe have consistently linked daily variations in air pollution to health, and a smaller number of longer-term cohort studies have also shown that air pollution raises the risk of death. According to estimates, long term exposure to PM causes a 1–2-year reduction in the typical population's life expectancy. The level of the risk associated with air pollution has a tendency to grow as a result of improved exposure categorization.

The number of negative health outcomes linked to air pollution exposure has been rising, and it is generally acknowledged that the cardiovascular effects are just as severe as, if not more so than, the effects linked to respiratory illnesses. Numerous plausible mechanistic pathways of injury have been identified in human clinical and animal experimental studies. One of these is systemic inflammation, which has been linked to atherosclerosis development and altered cardiac autonomic function, increasing the risk of heart attack and stroke. Strong evidence of the health advantages of reduced air pollutant concentrations has been revealed by intervention studies looking at dramatic drops in pollution levels. Notwithstanding ongoing ambiguities, the data generally tends to support the idea that ambient PM acting alone or in the presence of other covarying gaseous pollutants is at least partially responsible for PM impacts.

Brief Review of the Evidence

The health impacts linked to exposures to air pollution may be evaluated using analysing, toxicological, and clinical research as sources of evidence. These several areas of inquiry have produced complimentary results, and each has distinct advantages and disadvantages. When standards for airborne particles are determined, the results of epidemiological studies are given the most weight since they describe the effects of exposures that are really felt in the population. A significant body of epidemiological research has linked exposure to present levels of air pollution, particularly airborne PM, with increased mortality and morbidity, including a broad variety of detrimental cardiorespiratory health consequences. Countries or cities with comparatively low air pollution levels are included in this evidence.

Two different kinds of epidemiological research have been used primarily to evaluate associations between exposure to airborne pollutants and death. Cohort studies track large populations over time and often link mortality to a measure of typical PM exposure over the follow-up period. Studies using time series data look at the relationship between daily mortality and changes in recent PM concentrations. Regulatory bodies depend on the results of time-series studies to set limits for short-term exposures, whereas the results of cohort studies are used to establish yearly criteria. There are fewer long-term cohort studies of PM and mortality than there are studies of daily changes. They often need a large number of participants, extensive follow-ups, information on PM exposure as well as on possible confounding and modifying variables, and are costly to conduct. While two research from Europe were conducted, the majority of the investigations were conducted in the United States.

The largest impact on the creation of ambient AQ limits for PM10 and PM2.5 came from two cohort studies evaluating the health effects of prolonged exposure to air pollution in large populations: (1) The American Cancer Society (ACS) Cancer Prevention Study (Pope et al., 1995) and (2) The Harvard Six Cities Study (Dockery et al., 1993). While it has been said that these studies are uncommon, they do confirm the fundamental findings of the Six Cities and ACS that PM significantly affects mortality (Abbey et al., 1999; Chen et al., 2005; Gehring et al., 2006; Lipfert et al., 2006; Rosenlund et al., 2006).

The Six Cities Study was the first large prospective cohort research to show the harmful effects of long-term exposure to air pollution on health. This research showed that cardiovascular mortality is independently correlated with long-term exposure to air pollution. The increase in total mortality for the most congested city compared to the least polluted city in the sample of 8111 people with 14–16 years of follow-up was 26%. The fine particle exposure range for the six cities was 11.6-29.6 g/m3. In their 2006 extended obey of the Six Cities Study, Laden et al. discovered consistent effects of long-term exposure to particle air pollution.

The ACS research established a strong correlation between long-term exposure to PM2.5 and death over a 16-year period by linking chronic exposure to various air pollutants to mortality. Long-term exposures were most significantly linked, according to a follow-up study, to deaths from ischemic heart disease, dysrhythmias, heart failure, and cardiac arrest (Pope et al., 2004). For these cardiovascular causes of death, an increase in mortality risk of 8–18% was seen for every 10 g/m3 rise in PM2.5. Respiratory disease mortality revealed only moderately strong relationships. More recent analyses of the U.S. ACS data using more accurate exposure assessment techniques and focusing on neighborhood-to-neighborhood variations in urban air pollution in Los Angeles have discovered death rates from all causes and cardiopulmonary diseases that are at least two times higher than previously reported in analyses of the ACS cohort (Jerrett et al., 2006). The highest rate calculated from the initial ACS research (Pope et al., 2002) for all causes of death was 6%, but after accounting for neighbourhood confounders, the projected risk for a 10 g/m3 rise in the yearly average PM was roughly 11%.

AQ monitoring networks' measurements of ambient PM concentration are used in daily time-series studies to analyse changes in death counts from day to day in response to those changes. According to daily time-series studies, excessive PM exposure for a few days is often linked to a little rise in mortality risk. The National Morbidity, Mortality Air Pollution Study (NMMAPS), based on the largest 90 U.S. cities, shows that the increase in daily all-cause mortality risk is modest (0.21% per 10 g/m3 PM10; 95% CI, 0.09-0.33) but consistent with previous findings from large multicity studies in Europe (APHEA2: Smog and Health: A European Approach 2) and the United States (National Morbidity, Mortality Air Pollution Study (NMMA (Dominici et al., 2003; Katsouyanni et al., 2003). A review of time-series research carried out in Asia reveals that exposure to air pollution for a brief period of time is linked to an increase in daily mortality and morbidity.

The use of appropriate methods for assessing the degree to which gaseous pollutants (such as ozone [O3], NO2, SO2, and CO), air toxics, and/or bioaerosols may confuse or modify PM-related effects estimates is a significant methodological issue that affects epidemiological studies of both short- and long-term exposure effects (U.S. EPA, 2004). As all known gaseous pollution sources are known to have at least some negative health impacts that are also linked to particles, they are possibilities for confounding factors. Moreover, common sources may release gaseous pollutants and primary PM, and common weather variables may distribute them.

For instance, motor vehicles release both CO and particulates, and coal-fired power plants generate both SO2 and PM2.5. When Krewski et al. (2000) reanalyzed the Pope et al. (1995) research for the Health Effects Institute, they discovered significant relationships for both PM and SO2. Many fresh short-term PM exposure studies continue to document strong links between pollutants and mortality as well as numerous PM indices.

When the copollutant is included in the model, the estimated PM impact is comparatively steady, while the estimated PM effect in other cities varies significantly when some copollutants are added, especially NO2 (Burnett et al., 2004; Qian et al., 2007; Brook et al., 2007a). Notwithstanding ongoing uncertainty, the data generally tends to support that ambient PM acting alone or in th presence of one or more covarying gaseous pollutants is at least partially responsible for PM impacts (Burnett et al., 1997b; U.S. EPA, 2004).

There is a wealth of research suggesting that ground-level O3 significantly affects human health, notwithstanding the difficulty in distinguishing the impacts of PM and gaseous copollutants (Burnett et al., 1997a). As a result, AQ management actions that concentrate on lowering O3 have a reasonably lengthy history (Schere and Hidy, 2000), and ongoing efforts are needed throughout North America and across the globe. Future O3 levels in emerging nations are a severe worry due to a rise in the number of cars (such as in China) that produce O3 precursors, NOx, and volatile organic compounds as a result of economic growth (VOCs).

While O3 and related oxidants have historically been thought of as potent respiratory irritants that cause a wide range of morbidities, recent research shows that acute exposure to O3 is also associated with an increased risk of mortality, particularly during the springtime or warm season when O3 levels are typically high. For instance, studies conducted in 23 European cities (APHEA) and 95 U.S. towns (U.S. National Morbidity, Mortality Air Pollution Study (NMMAPS)) both revealed positive and substantial O3 impact estimates for all-cause (nonaccidental) death. There is strong evidence between ambient O3 levels with non-accidental and cardiopulmonary-related mortality, particularly during the warm O3 season, according to three recent meta-analyses that looked at possible causes of variability in O3-mortality correlations.

According to the U.S. EPA's most current O3 criterion documenteffects brought on by O3 exposure are unrelated to PM. O3 develops in the atmosphere (i.e., is a major pollutant), therefore its temporal variability is often not connected with other pollutants (e.g., PM10, CO, SO2, and NO2). As a result, this distinct impact has been very simple to identify. Yet, during the summer, O3 might have a stronger correlation with secondary fine particles. O3-mortality relationships do not, however, seem to be significantly changed in factors time-series models that also include PM10 or PM2.5, according to research conducted in many cities and in a single city (Burnett et al., 2004). These findings imply that O3 seems to have strong impacts on respiratory health outcomes that are separate from those of other contaminants.

The American Heart Association has acknowledged that there is a causal link between airborne particles and poor cardiovascular outcomes as a result of growing research on cardiovascular outcomes (Brook et al., 2004). Atherosclerosis and long-term exposure to fine particles are linked, according to recent epidemiological, clinical, and toxicological investigations (Künzli et al., 2005;

Sun et al., 2005). Many recent investigations have shown links between ambient PM2.5 and subtly altering cardiovascular effects including blood pressure, vascular function, or changes in cardiac rhythm.

Premature mortality, hospital admissions, and ER visits have been the main subjects of a large portion of previous epidemiological research on the effects of short- and long-term air pollution exposures. Nevertheless, more recent research has looked at a wider range of health issues, including asthma and chronic obstructive pulmonary disease (COPD) flare-ups, children's respiratory health, and various unfavourable cardiac and reproductive outcomes.

Effects on vulnerable subpopulations, such as children and older individuals, as well as those who already have cardiac and metabolic diseases, have also been studied in more detail. The list of health endpoints linked to PM exposures has also grown to include: effects on developing children and infants; markers of inflammation; indicators of changes in the heart's rhythm and blood pressure; increased risk of making atherosclerotic plaques more susceptible to rupture, clotting, and ultimately causing heart attack or stroke; and indicators of the appearance of atherosclerosis with prolonged PM exposure (U.S. EPA, 2006a). Several of the intermediate result indicators may have long-term consequences for people that are yet to be determined, but they at the very least provide important information about possible biological pathways.

There are molecular reasons for the findings that people with diabetes are more susceptible to the cardiovascular consequences of air pollution Significant correlations between PM2.5 and diabetes fatalities, as well as overall mortality in individuals with a history of diabetes, were observed by Goldberg et al. in 2006. Those with diabetes mellitus may have a twofold increased acute risk of cardiovascular events compared to non-diabetics. With the rising prevalence of diabetes in North America and certain prevalence-based data suggesting that exposure to chronic air pollutants may play a role in the development of type II diabetes, these results are especially concerning (Brook et al., 2008). There is strong evidence to suggest that exposure to PM in children is linked to poor normal development, worse asthma, and a higher prevalence of cough and bronchitis. Also, there is evidence to support a link between rising PM concentrations and a higher risk of postneonatal respiratory death (adjusted odds ratio of 1.16 for a 10 g/m3 rise in PM10). Research implies a connection between air pollution and birth weight, premature births, and retardation of intrauterine growth.

According to the World Health Organization's report on the "Health Effects of Transport-Related Air Pollutants" (WHO, 2005c), the evidence suggests that pollutants from vehicular traffic increase the risk of non-allergic respiratory symptoms and disease as well as the risk of death, particularly from cardiopulmonary causes. New research, supporting this conclusion and extending the health endpoints to other morbidity outcomes, continues to be published as a result, among the several factors contributing. While most epidemiological evidence linking air pollution exposures to health effects focuses on measures of AQ and health in North America and Europe, indoor pollution from the use of biomass fuel occurs for millions of people living in developing countries at concentrations that are orders of magnitude higher than what is currently seen in the developed world. This is a public health problem with implications for children and adults worldwide. Acute respiratory infections in children caused by these exposures are thought to result in over 2 million annual deaths, according to estimates. There is still a lot of evidence that additional air pollution reductions, even in very clean nations and cities, will have a large positive impact on public health and the economy regardless of the extent of the exposure and, generally, the source.

AQ Management Framework

The challenge of managing AQ is made more difficult by the absence of health impact criteria. It indicates that determining the proper degree of reduction (i.e., the ambient goal or emission controls required to decrease effects to an acceptable level) can only be done by a quantitative study of risks and benefits, maybe represented in economic terms (i.e., cost–benefit analysis). There will come a time when costs exceed benefits, assuming that the additional costs of achieving a particular lower ambient concentration rise as this concentration drops. Theoretically, this strategy seems workable, but there are many variables to take into account, including knowledge of AQ science, health science, engineering, and socioeconomic considerations, the latter of which may change greatly from nation to country and over time. With the available data, the cost-benefit analysis method used to determine an acceptable level of risk and the ensuing emission reduction objectives can only aim to be as thorough as possible and must engage stakeholders* from both sides of the argument. This also applies to using integrated risk models to calculate the benefits of various policy alternatives.

Multiple pollutants, including separate size and chemical fractions of PM, as well as present and future connections to climate change and other atmospheric issues, like acidic and toxic depositions, must be taken into account when developing policies, whether or not a cost-benefit analysis is performed. The "one atmosphere" method is a term used often to describe the process of integrating the examination of several concerns. The Clean Air for Europe study (CEC, 2005) is one of the first initiatives to statistically assess various air challenges. The examination of AQ management alternatives might ideally be expanded to include principles of long-term sustainability and whole-lifecycle management.

A solid scientific knowledge foundation from studies on air quality, atmospheric chemistry, and emissions is crucial because it gives us the tools to connect emissions to changes in human health or the environment by the interaction between research, policy, and stakeholders, this helps the creation of policy for AQ management. Such regulations may be based only on AQ requirements and their advantages (health and/or environmental), or they may consider the expenses of reducing a given emission as well as the financial advantages of bettering ecosystem and human health.

AQ Models and Emission Inventories

Policymakers may estimate future air concentration and deposition patterns using AQ models, which are based on potential future emission rates. In real life, a modelling system similar to the one shown is used to quantify the relationship between emissions of primary pollutants or precursors of secondary pollutants and ambient pollutant concentrations. The depiction of emissions, transport, diffusion, and removal processes is at the core of this system. An emissions processing system and a numerical weather prediction model (Seaman, 2000), respectively, supply the emissions and meteorological data required to "drive" an AQ model. Chemical changes in the atmosphere must also be taken into account for the majority of applications. This necessitates that the models take into account time scales ranging from fractions of seconds to days, resulting in model domains that span from the Earth's surface up to at least the ce6ntre of the troposphere in the vertical and at least many hundreds of kilometres in the horizontal.

Pollutant concentration fields as functions of place and time for a certain set of pollutant emissions and climatic circumstances are the primary outputs of the AQ modelling system Then, this knowledge may be expanded to include other physiologically, ecologically, and optically significant aspects of the ambient pollution mix.

In order for AQ models to be effective, data on the area of interest's emissions and atmospheric observations must already be accessible. Because of the larger uncertainties associated with model projections that result from the uncertainties in the model inputs, AQ model implementations for that area if such data are not available seldom give any relevant advice for policymakers. For many years, AQ management has been supported by AQ models. They have developed continuously and quickly over this period. Considering this background, several overviews of AQ models and AQ modelling have been published throughout the years.

1. A qualitative mental model for a place is an AQ conceptual model.
2. It is based on a synthesis and reduction of the knowledge about AQ that is already accessible.
3. using emissions analysis, measurement analysis, and model outputs to extract the major
4. significant elements, such as major sources of emissions, the peculiarities of the terrain, and local climate and weather. Results of the model for a variety of climate scenarios, from
5. source apportionment studies, particularly sensitivity assessments, may considerably creation or elaboration of a mental model. a manifestation of the growth. The analysis for PM provided by Pun and Seigneur (1999) is an example of a conceptual model.
6. pollution in the San Joaquin Valley in California. In places where the availability of
7. emissions information, measurements, and model output may all make substantial contributions to the conceptual model development, as shown by Zunckel et al. (2006) for south African Africa. Relationships between sources and receptors are often crucial to an AQ conceptual model.

The zero-out method measures source-receptor connections. This is, emissions from a certain region or from a specific source industry (for example, from both from heavy-duty diesel vehicles and from electric power production) are turned off, and All other emissions remain unaltered. Then, predictions from this example may be removed. based on forecasts from a base run with each emission source present in turn to determine the desired source sector's or jurisdiction's influence. "Source tagging" and inverse methods are two more advanced techniques. The former contains a pollutant.

The approach tracks emissions from certain source sectors or geographic regions concurrently as different ("tagged") species (Kleinman, 1987; McHenry). Kleeman and Cass, 1999a,b; Zhang et al., 2005; et al., 1992). The adjacent area in the latter AQ model may be built, allowing researchers to determine how sensitive the model is to emission inputs, followed by the addition of ambient measurements, or alternatively initial Based on the synthesis inversion approach, attribution outcomes may be improved.

The accuracy of the input emissions may also be inferred through a comparison of model predictions and observations. For instance, if model forecasts are consistently high or low in a particular location compared to observations, a high or low bias in the input emissions for that region may be one potential explanation. This methodology was used by Yu et al. to compare forecasts and emissions between rural and urban locations (2004). Another, more quantitative method for estimating emissions strengths on a regional or global basis is through inverse modelling analyses, in which improved models are combined with ambient measurements (

To produce an AQ prediction for the next one or two days, a model may be run in "real time." With this knowledge, sensitive people may be advised to take precautions to limit their exposure, and short-term interventions on certain sources can be put into place. Regularly disseminating predictions promotes or maintains public knowledge of AQ, and forecast reviews may reveal model flaws under a variety of circumstances.

Modeled pollutant fields may be taken into account while configuring networks in order to help them better reflect the "real" geographical pattern. In order to evaluate the effects of adding or deleting fictitious stations from a network on the estimate of the real pollutant spatial pattern, different numbers and locations of grid cells may then be sampled. Similar to how scientists can use model predictions to aid in identifying measurement locations for stationary instrumentation and sampling tracks for the deployment of aircraft and other mobile sampling platforms, scientists can use model predictions to aid in planning and designing a field experiment. Because models' output is based on thorough representations of physical and chemical rules, they may also be used as complex interpolation techniques. displays an illustration of a "fused" model and measured O3 concentrations. The ultimate objective of models is to operate constantly in prediction mode with four-dimensional data integration in real time. The measurement data utilised will likely come from a variety of surface- and space-based (satellites) remote sensing datasets as well as in-situ measurements.

The optimum representation of the chemical and physical condition of the atmosphere will be stored in the predicted fields. Last but not least, AQ models provide a way to illustrate and connect in a single document our best comprehension of all the chemical and physical processes pertinent to AQ. New insights are frequently discovered, furthering knowledge, when this knowledge synthesis is assessed by contrasting model predictions with enhanced measurement datasets from focused field campaigns In the end, this produces better numerical and conceptual models, which can subsequently provide more accurate data on AQ risk management.

While utilising an AQ modelling system to analyse a problem, there are several decisions to be taken and factors to take into account. It is crucial that consumers of model findings be aware of these decisions when assessing the dependability and robustness of the given advice, as will be covered in the sections that follow. Identifying the questions which need to be addressed is the first stage in implementing a model. Finally, if feasible, a conceptual model should be found or created in order to reduce the number of numerical AQ models that might be utilised to provide an answer. A model with complicated chemical interactions may not be required for extremely local effects by a point or line source, for instance, or a thorough but computationally costly model may not be the best option for running a multiyear simulation. Another thing to keep in mind is that a model created to solve one problem (like photochemical smog) could not contain all of the processes required to address another one (e.g., deposition of acidic species). Moreover, a model created for heavily contaminated atmospheres may not be suitable to mimic a clean atmosphere, and the opposite may be true (e.g., regional atmospheric chemistry in emission source regions versus background global chemistry).

Additionally, there are numerous options when setting up a model run, including (a) the domain location and size (horizontal and vertical), (b) the map projection to be used, (c) the grid spacing (horizontal and vertical), (d) the integration time step, and (e) the simulation period, which includes any necessary "spin-up" time (the period of time for atmospheric concentration fields to reach an equilibrium between emissions and r). Every decision has consequences. A putative hot spot, for instance, may be "averaged out" by using a high horizontal grid spacing, or small-scale meteorological circulations induced by regional topography characteristics might not be represented. For discussion on the selection of horizontal separation distance, Berge et al. (2001) on the specification of chemical beginning conditions, and Brost (1988) on the definition of chemical lateral boundary conditions, see U.S. EPA (2005b).

Gaps in scientific knowledge of the relevant contaminants might be a major constraint for models. For instance, despite the fact that the carbonaceous component of atmospheric PM2.5 normally makes up between 40 and 50 percent of the total mass of PM2.5, it is widely recognised that the origins of a large portion of this component are not currently understood. Another example is the incomplete knowledge of the chemistry of midnight NOx.

The use of process parameterizations in existing models that are only partially faithful to the actual atmosphere is a second drawback. For instance, Dabberdt et al. (2004) has pointed out the need for better studies of the impact of clouds and cloud processes on AQ, as well as the interaction of the planetary boundary layer and clouds. The interpretation of model predictions and the development of potential emission control methods may both be made more difficult by nonlinear reactions. As a possible issue for acid deposition, the 1980s saw the identification of the potential for a nonlinear response in sulphate deposition to SO2 emission decreases caused by oxidant restrictions (Misra et al., 1989). O3 photochemistry has well-known nonlinearities (Seinfeld and Pandis, 1998), whereas PM chemistry has even more. Model estimates for O3 control scenarios for a Los Angeles smog event were provided by Meng et al. in 1997. O3 levels were decreased while PM2.5 mass increased as a result of lower VOC emissions. Because of "nitrate substitution," decreases in SO2 emissions can result in increases in PM2.5 concentrations.

Gaps in scientific knowledge of the relevant contaminants might be a significant model restriction. For instance, it is generally known that many of the origins of the atmospheric PM2.5's carbonaceous component are still unknown, despite the fact that this component normally makes up between 40 and 50 percent of the overall mass of PM2.5. Another example is the incomplete knowledge of midnight NOx chemistry (Brown et al., 2006). Another drawback is the use of process parameterizations in existing models that are only partially accurate to the actual atmosphere. For instance, Dabberdt et al. (2004) has recognised the need for enhanced treatments of the effect on AQ of clouds and cloud processes as well as the planetary boundary layer. Interpreting model results and developing potential emission control strategies may become more challenging as a result of nonlinear reactions. The 1980s saw the identification of a possible issue for acid deposition: the likelihood of a nonlinear response in sulphate deposition to SO2 emission decreases caused by oxidant restrictions (Misra et al., 1989). There are well-known d. in O3 photochemistry (Seinfeld and Pandis, 1998), but PM chemistry has even more nonlinearities. During a Los Angeles smog occurrence, Meng et al. (1997) provided model projections for O3 control options. O3 levels dropped as a result of lower VOC emissions, while PM2.5 mass increased. In certain circumstances, nitrate replacement causes PM2.5 concentrations to rise along with reductions in SO2 emissions.

As it often necessitates the solution of sizable linked systems of both ordinary and partial differential equations, numerical integration of the model also adds inaccuracies. Among others, Pielke (1984) and Jacobson (1999) have both described how to use finite differences in both time and space. Truncation errors for any time-stepping scheme used to integrate the AQ model through time depend on the order of the scheme and the size of the time step that is selected. In order to compute each process parameterization individually, operator splitting is often used on the right-hand side of the governing equations. Nevertheless, operator splitting also introduces errors and depend on the order of the splitting and the total time step. It is generally recognised that advection is a challenging problem to solve, and literally thousands of numerical methods have been created to address this problem. Truncation mistakes, numerical drift, phase errors, a lack of positive definiteness, and a violation of mass conservation all affect everyone to variable degrees.

Another crucial factor is model "resolution." The grid-cell size (Dx) and discrete model time step (Dt) choices impose implicit numerical filtering on the model solution. In essence, the model cannot predict any temporal or spatial characteristic less than 2Dt in time or larger than 2Dx in size; however, 4Dt and 4Dx are likely a more realistic barrier. For processes taking place at more compact temporal and geographical scales, this has significant ramifications (Pielke and Uliasz, 1998). Many parameterization techniques have been created as a result to reflect the impact of subgrid-scale phenomena at grid sizes. The depiction of point source emissions is a clear example. As emissions are expected to be well-mixed over at least one grid cell, all or most point sources in any Eulerian (i.e., grid) model will be represented as volume sources. This introduces significant numerical (i.e., artificial) diffusion in the region of significant point sources. The correctness and representativeness of these input datasets, which are crucial for the successful functioning of numerical AQ models, are a major challenge. Even with a flawless model, the saying "garbage in, trash out" will still be true. The following are some examples of model input datasets:

It is necessary to provide the emission rates of various gaseous and particulate species for each model time step for each model grid cell at all levels. The errors in the emission inventories themselves, as well as the additional uncertainties brought about by the emissions processing systems that carry out the chemical speciation for PM and VOCs, as well as the spatial and temporal disaggregation steps required to produce model-ready emission files, that everything contribute to the significant uncertainty (Hogrefe et al., 2003). Further data on smokestack properties, such as stack height, stack diameter, stack-gas exit velocity, and stack-gas exit temperature, are required for large point sources. Current emission inventories must be adjusted and changed in order to take into account all of the assumptions made in a future-year scenario. Since emissions data are such a crucial.

Another difficulty is the number of resources needed. When it comes to model input data, personnel, calendar time, and computer power, AQ modelling is often resource-intensive (Reid et al., 2003). The above-mentioned input datasets, such as emissions, hydrological, and geophysical files, must be prepared for the model configuration chosen in order to apply a model to a specific scenario. The model must then be run, and the results must then be processed, evaluated, and understood. A minimum of three highly skilled modellers, notably an expert in emissions processing, a specialist in weather prediction, and an expert in air quality modelling, are often needed to participate.

From beginning to end, including setting up and testing the model for the application, the needed amount of work will most likely take months rather than a few weeks. A high-end PC with many CPUs, enough of internal memory and disc space, plus off-line archiving devices to save numerous large model output files would be the bare minimum of computing resources required. Another need is having access to emissions, meteorological, geophysical, and air quality monitoring data.

Comparing model predictions with environmental data also raises a variety of problems. The main one is incommensurability, which results from the fact that measurements are often taken at points in space or along lines (for example, aircraft flight tracks, DIAL), but model projections correspond to grid-volume averages. How typical would a single point measurement be of the 20 km3 of air included in, say, a regional-scale model with a lowest grid volume of 20 km × 20 km by 50 m?

The daily fluctuation at the sub grid scale (80 km 80 km) was found to be roughly linearly proportional to the mean level in eastern North America. The biggest variability was linked with SO2 and minimum O3 (0%) among the pollutants detected at 3-5 stations within a grid cell. The intermediate variability was associated with p-SO4 (30%) and t-NO3 (40%), while the lowest variability was associated with maximum O3 (20%). (Seilkop, 1995a,b). At these scales, it is evident that uncertainties resulting from comparing a single point measurement to a model value outweigh uncertainties brought on by equipment error. The Los Angeles basin SCAQS research from 1987 discovered that local inhomogeneities for O3, NO2, and CO had normalised gross errors in the 25–45% range within smaller circular regions (25 km radius).

The need to compare "apples with apples" when comparing model projections with ambient data is a second challenge. Although some networks report observations at temperature and pressure, AQ model projections for gas-phase species, for instance, correspond to ambient circumstances (STP). When comparing PM, model projections for PM are made using the Stokes diameter, but actual PM measurements are reported using the aerodynamic diameter. The distinction between elemental carbon (EC) and organic carbon (OC) is measurement-technique-based and can vary from network to network, and PM measurements, unlike model predictions of PM, can also be affected by artefacts related to volatile species like nitrate, some organic compounds, and aerosol-bound water (Fan et al., 2003). (Seigneur and Moran, 2004). Model uncertainty depends on a variety of variables, some of which are application-specific, as well as how these variables interact. Thus, it is impossible to measure total unpredictability Uncertainty in the model comes from three basic sources.

The spectrum of uncertainty may be attempted to quantify by comparing the results from parameterizations and even complete models. Certain individual unknowns can be quantified, especially for numerical approaches, to discover model sensitivity to different inputs and parameters. The presentation of novel numerical methods and parameterization approaches often includes an error characterization section. To determine which model inputs and parameters have the greatest impact on the chosen model outputs, a variety of sensitivity analysis approaches, including as DDM, ADIFOR, FAST, variational techniques, perturbation theory techniques, Green's function techniques, and stochastic techniques, may be utilised.

The effects of various parameterization approaches may be contrasted when embedded in a host model in addition to being examined side by side outside of models (Padro et al., 1993; Mallet and Sportisse, 2006). The effects of various modelling system components may also be assessed at a higher level. Hogrefe et al. (2003), for instance, examined the effects of utilising emissions files created by two different emissions processing systems from a single emission inventory upon those predictions of one model. They discovered variations in anticipated daily maximum 1-hour O_3 concentration on the order of 20 ppb. Smyth et al. (2006b) examined the results of two sets of meteorological input files for the same time that were given by two separate meteorological models using outputs from one emissions processing system and one regional PM model. For the two sets of meteorological files, on average, their performance (operational evaluation) was roughly equivalent, as was the performance of the AQ model. However, when grid cells were matched for the same time, significant variability was seen, especially in aerosol quantities affected by relative humidity. Seven models' performance in forecasting O3 for the same time period (summer 2004) and area was compared (eastern United States). Interestingly, none of the models alone could equal the accuracy of a weighted average of the seven projections, even if the range of predictions often fell within the measurement range.

By combining expert views, one may analyse uncertainty in a different way. Seigneur and Moran (2004), for instance, created a chart that displayed qualitative evaluations of PM modellers' degree of confidence in key features of the values predicted by the most recent PM AQ models. So2, NOx, and p-SO4 air concentrations were the only model components deemed to have a "high" degree of confidence. A few elements, namely secondary OC and PM ultrafine mass and number concentrations, received "extremely low" ratings whereas the majority of aspects received "medium" or "low" ratings. These ratings were developed based on an evaluation of all relevant uncertainties, including those related to the emissions of various pollutants and to scientific knowledge.

Generating Emission Inventories

A crucial model input is accurate data on the emissions of several particulate and gases chemical species. It is impossible to determine which sources are most crucial to control, to predict the effects of these emissions on AQ, or to track the success of emission reduction programmes without accurate information on the sources of air pollutants—what they are, where they are located, what they emit, and how much. Current and reliable historical emission inventories.

Government and business both have an obligation to cooperate at various levels in order to get emissions data. In a perfect world, specific industries would continuously monitor and report their emissions, while local and national governments would compile data and run models to extrapolate the information across sources, moment, and space, and AQ modellers and field measurement experts would assess the information. Emission inventories and models must include quantitative estimates for several source categories at the federal, state or provincial, and county (or their equivalent) levels in order to be most useful. This data is required for NOx, SO_2, CO, fine particle mass, coarse particle mass, VOCs, NH_3, and CO_2 at the very least. Also, it is necessary to categorise the particles and VOCs into a number of groups that represent chemical composition in a way that interacts with chemical pathways in models and would enable some evaluation of environmental and health hazards.

ER (0 ER 1) is an emission reduction factor that takes into account any emission control measures that may be implemented to the source, and E is the emission rate (for example, kg/h or tones/year) of a certain pollutant. EF and A are the emission factor and activity factor, respectively. The mass of a certain pollutant or chemical species released per unit process variable is known as the emission factor, or EF. The associated process variable, or activity factor, A, includes things like the volume of gasoline spent, the distance a car travels in a given length of time, and so on. In actuality, emission factors and emission reduction factors might differ across sources as well as depending on the amount of the activity factor, the kind of fuel used, the operating environment, the age of the source, the location, the season, and other considerations. More complicated emission models have been created for very complex categories like mobile source emissions since not all of this complexity can be adequately represented in such a basic connection (Miller et al., 2006).

Emission factors or their equivalents are often based on measurements, however this is not always the case. Large point sources, such as electric generating units or stack emissions from significant industrial processes, are the simplest source type to describe. Emissions from multiple, widely scattered individual sources are more challenging to measure. Examples include fugitive emissions from industrial sources (i.e., unintentional emissions), natural emissions from vegetation, agricultural emissions, pollution from small industrial or commercial sources, emissions from residential sources (e.g., PM emissions from cooking or space heating), and emissions from large-scale biomass burning. Direct measurements for these kinds of emission sources could be challenging, or they might only be practical for a limited subset of the sources in issue. Estimates of emissions are more uncertain as a result of all of these variables than they are for big point sources. These uncertainties may be as little as a factor of two or as big as completely omitting a source or chemical precursor that turns out to be important upon further examination.

An major, although widely dispersed and changeable, component of pollutant emissions may be seen in the on-road and off-road mobility sources (such as cars, trucks, aeroplanes, railroads, construction equipment, ships, etc.) that contribute to emissions of pollutants. The conventional method for estimating vehicle and truck emissions involves measuring emissions from dynamometer testing of representative cars and trucks in a lab setting after typical driving cycles. These readings are fed into intricate mobile source emission models that make an effort to recreate the operating characteristics of vehicle fleets in a variety of urban, suburb, and rural settings. The issues with dynamometer testing include that they may not accurately reflect the range of fuels utilised, driving cycles or circumstances, environmental variables, and states of repair of the real cars in use. They may also have a small enough sample size to not be statistically significant.

serves as the foundation for the majority of the information presented in inventories since the majority of sources lack continuous emission sensors to measure actual emissions. The activity factor is equally significant, despite the fact that the value of the emission or the emission reduction factor are often in the spotlight. Activity factors may be created using data from processes that are continually monitored, however similar to continuous emission monitors, these data are often in short supply. Activity factors are often created using data on economic activity or activity surveys. Data on economic activity that are gathered for purposes unrelated to emissions but may be utilised in the creation of emission inventories include data on fuel usage. Emissions from off-road construction sources may be developed using information on construction operations. Data on emissions from household woodstoves, fireplaces, and open burning may be provided to inventory developers through population densities and activity surveys. Estimating the kinds and densities the vegetative cover, which is then used to estimate biogenic emissions, may be done with the use of land-use maps and satellite data. In each scenario, data gathered for other objectives, such as tax calculation, economic development, etc., land-use planning, may be used to create emission estimates.

Costs of Emission Inventory Development and Improvement

The expense of creating an emissions inventory is determined by the amount of information taken into account in the final product's determination and output files. Quantifying emissions of certain hazardous air pollutants, such as mercury and other metals or the speciation of organic compounds found in flue gases at extremely low quantities (NARSTO, 2005), also adds significantly to the cost but enhances the performance of AQ models. An inventory will be less costly if it is created using data that already exists on the emission factors rather than by doing a thorough analysis of how representative the available factors are. Now, the U.S. federal government spends around $25 million annually developing and updating emission inventories throughout North America (NARSTO, 2005). This does not account for the expenditures made by state and local governments, which are estimated to be around $10 million annually, or the additional expenditures that would be necessary to address the deficiencies found in the current inventories, which are estimated to be around $35 million annually (NARSTO, 2005). Without taking into account municipal and provincial efforts, Canada invests roughly $6 million (U.S.) year in creating its national inventory, while Mexico has spent about $600,000 (U.S.) annually creating its National Emission Inventory.

Weaknesses of Current Emission Inventories

Nowadays, AQ managers in many nations have a thorough understanding of the emissions from significant point sources and have made use of this expertise to create efficient steps for lowering those emissions. The significance of spontaneous and biogenic emissions has been acknowledged, and models for predicting emissions from mobile sources have continually improved. Yet there are still a number of serious flaws:

Creation of mobile source inventories, especially with relation to VOC speciation. Emissions from a variety of local sources, including those for significant categories such biogenic emissions, ammonia, fugitive emissions, and open burning of biomass. Since there are so many of these compounds, so many potential sources (many of which are local sources), and so little data for establishing emission factors or speciation profiles, emission estimates for air toxics (such as the 187 hazardous air pollutants designated by the U.S. EPA) are particularly uncertain. There is need for improvement in a variety of source categories when it comes to PM emissions, and more specifically, its chemical components, size distribution, and significant precursors that are volatile and semivolatile. There is little knowledge about some of the sources that contribute a lot of carbonaceous particles (OC and EC).

As there are only a few emission measurements available, it is important to carefully consider how well emission estimates reflect actual activity. It is challenging and a source of unquantified uncertainty in model findings to gather data on emissions with the spatial and temporal resolutions required for location-specific AQ modelling and intraurbanscale exposure assessment.

CHAPTER - 16

EVALUATING UNCERTAINTY IN EMISSION ESTIMATES

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It is more effective to gather the data required to measure uncertainty at the time the emissions data are created, and quantifying uncertainty is a crucial "best practise" in inventory production. Some important considerations:

The variance in emissions caused by changes in source operating circumstances or between the several sources that make up a source category is often not taken into account by emission factors. The processes and emissions that may be affected by new technologies may not be represented in the emission factors that were developed using the original method. The real operation and thus the actual emissions are not adequately represented by emission factors that are based on idealised activities, such as the usage of vehicle operating cycles.

The provided inventory figures are further questionable due to measurement biases or mistakes. There may be inaccuracies in the geographical, temporal, or chemical data utilised in AQ models as a result of these variances, which may be related to the location, timing, or composition of emissions. In general, when models are used to predict changes in AQ over longer time periods and over geographic regions that are of the same order of magnitude as the spatial scale covered by the inventories, emission uncertainties tend to have a reduced influence on comprehension and AQ management choices. In other words, estimations of the national yearly average pollutant concentration likely have lower levels of uncertainty than those for the concentration during a single day in a particular metropolitan area.

It is more probable that the discrepancies between actual and anticipated emissions based on emission variables will average out over a longer time period and a larger region. More thorough emissions data is needed, nevertheless, as AQ models get more complex in order to answer more precise AQ management issues. Using emission estimates based on an annual average emission factor, it is impossible to confidently model atmospheric processes over the course of an hour with more intricate chemical reaction mechanisms and in smaller locations. This would have a high likelihood of resulting to inaccurate population exposure estimates, inaccurate AQ predictions, wrong identification of the most significant sources within a particular region, or inaccurate estimates of a specific emissions that need to be regulated for a certain source type.

The most severe uncertainties are those related to non-point-source emissions, and there are often two methods used to estimate them: top-down and bottom-up. The various observations or parameters that make up the emission model's uncertainties (bias and random error) are evaluated using the bottom-up method, and these uncertainties are then represented as a probability distribution function (pdf). Next, in order to offer an estimate of the confidence in the emission estimate, these uncertainties are propagated through the model, often using a Monte-Carlo technique.

The sensitivity analysis is an alternate bottom-up strategy. Evaluating the sensitivity of an emission-model output to its different input values in terms of the partial derivative of the output of the model to the relevant input parameter is a straightforward kind of sensitivity analysis. This method provides a measure of how much the emission estimate would vary for a given change in an input parameter, indicating the relative sensitivity of the emission model to its different inputs and enabling a basic assessment of uncertainty.

Ambient measurements or other independent data are used to assess the accuracy of the emission estimates in top-down reviews of emission inventories or emission models. Applications of top-down assessments that simultaneously examine the original bottom-up inventory data are the most successful since this allows for the source of the problems to be found rather than just claiming that the inventory is inaccurate (Miller et al., 2006). Comparing temporal trends in emission estimates with historical trends or comparing trends in ambient pollutant concentrations (or in ratios of pollutants) with the trend in estimated emissions under circumstances where the effects of transportation, chemical transformation, and removal can be ignored or taken into account are two top-down approaches. Parrish et al. (2002) and CRC both present the findings of this kind of investigation (2004). NARSTO describes this strategy in detail as well (2005).

Alternative methods for estimating emissions (such as contrasting vehicle emission estimates based on vehicle distance travelled with those based on total fuel consumption), source apportionment methods, and inverse modelling are additional top-down approaches for evaluating emission inventory uncertainties. Several multivariate statistical approaches are used in source apportionment (or receptor modelling) strategies to estimate source kinds, source locations, and relative contributions from ambient observations (Watson and Chow, 2005).

As no model is flawless, we must acknowledge this before using any to AQ management. How can we then utilise models to guide AQ management while taking into account the ensuing uncertainty in a justifiable and fair manner? A model probably has to be believable in order to be helpful. In other words, it must have shown to be competent and reliable enough for analysts and decision-makers to employ its forecasts in the creation of AQ management plans. In turn, confidence can be increased in two different ways: first, by applying the model in a way that is as appropriate, transparent, and defendable as possible for the AQ issues under consideration; second, by performing model performance evaluations that characterise the model's performance and quantify its errors.

Before a model is used in the realm of policy, it should always go through model verification and performance assessments. According to Russell and Dennis (2000), model verification entails evaluating the consistency, completeness, and accuracy of a model's design, science, process representations, techniques and numerical methods, inputs, and source code. Model verification evaluates the accuracy, reality, or truth of a model. Peer review is the most effective method for doing this, and the model source code should be freely accessible to everyone who is interested.

By comparing model predictions with observed AQ data and/or predictions from other models, model performance assessment examines and evaluates model performance (Fox, 1981; Dennis et al., 1990; Russell and Dennis, 2000). There are at least six primary categories of model performance evaluation:

It's also critical to think about the model performance metrics that need to be assessed. The majority of AQ model assessments take the form of case studies, where a model is run for a certain time using input emissions and weather appropriate for that period, and the model performance is then assessed using measurements from that same period.

Yet, the most typical use of AQ models is to assess how changes in emissions may affect AQ. The main component of model performance in this case is how effectively the model predicts the atmospheric reaction to the change in input emissions, necessitating a somewhat different method for performance assessment. In order to determine an atmospheric reaction, AQ measurements for two distinct periods are necessary for a direct assessment of model response. As a result, the AQ model must be run for the same two periods using different input emissions corresponding to the two periods. It's critical to be aware of difficulties like I the need to employ emissions for two separate time periods calculated using a consistent technique, and (ii) the extra unpredictability brought on by interannual meteorological variability while carrying out this operation. While few published model-response assessments exist, some do exist (Moran and Zheng, 2006). Also, keep in mind that a model-response assessment is the same as the evaluation of model-predicted relative reduction factors in terms of U.S. regulatory modelling language.

the choice of the model domain, grid resolution, and model configuration; the preparation of the model input files; the execution of the model; and the post-processing and analysis of the model predictions. The outcomes produced by the modelling system may be affected by all of these processes, thus it is crucial to carry out the modelling process in a justifiable and logical manner.

The majority of these stages, which are explained in greater detail below, are applicable to any application of an AQ model. It may not be feasible to complete the task as thoroughly as policymakers and modellers would want due to the open-ended nature of some of these processes and the realities of few resources. Yet, making poor forecasts might (or might not) be the result of "cutting costs. It's crucial to make sure that the AQ model's inputs are as precise and reliable as feasible. The suite of meteorological parameters taken into consideration should include temperature, humidity, wind speed, wind direction, cloud-related fields, precipitation, and, if possible, planetary-boundarylayer depth. At the very least, an operational evaluation should be conducted against meteorological measurements

Run a base-case AQ simulation and assess the outcomes. It is necessary to assess the performance of the AQ model for the base-case time periods in order to describe and quantify the performance of the whole modelling system (i.e., including the handling of emissions and meteorology) and to decide if that performance is acceptable. Russell and Dennis (2000), Reid et al. (2003), Seigneur and Moran (2004), and the U.S. EPA (2001, 2005b) have all argued that given the known model limitations, errors, and uncertainties, this performance evaluation for the base case should not be limited to just a basic operational evaluation against measurements of one or two pollutants, but instead should include a wide range of analyses that all feed into a "weight-of-evidence" judgement.

Every time an AQ modelling system is used, compromises are necessary. Nonetheless, if AQ modellers want to provide their customers the best advice possible, they should see the eight-step set of modelling best practises mentioned above as a goal to be pursued as closely as feasible. Generally, the best AQ modelling practise is most easily attained and maintained when a knowledgeable core of specialists who have prior expertise in the relevant jurisdictions are kept and adequately supported in terms of funding and national and international interaction. A conceptual model for many situations is likely to exist if such a group is active; AQ modelling may have been done, input datasets are often accessible, and there is frequently prior experience researching emission scenarios. As a result, the required degree of credibility is consistently established, and the information infrastructure will continue to develop and improve such that the majority of new AQ management concerns may be reviewed beginning at Step 5. Step 7 may not be necessary if the basic scenario has already been thought of, making Step 8 the absolute minimum need for a new modelling research.

Assessing Health Effects

The core of AQ health studies and the CRFs developed from this study are measurement data and, most often, data from regular monitoring. In the end, measurements might provide fresh understanding of the particular contaminants or sources that pose the most threat to human health and the environment. To maintain advancing understanding, a variety of health study methodologies and thorough AQ and exposure assessments are required. The WHO examined approaches and procedures for delivering enough ambient AQ information for health effect assessments. CRFs based on direct connections between ubiquitous observations of a variety of air pollutants, as detected by conventional monitoring networks, and acute and chronic consequences happening within the general population, are essential for AQ risk management.

Establishing "real-world" linkages also proves that the impacts of air pollution are relevant to actual circumstances. This makes it necessary to continue collecting ambient data in order to assist research on the health effects of both acute and chronic exposure. Finding CRFs for individual pollutants and pollutant combinations that are adequate for risk management or cost-benefit analysis is one of the main issues when dealing with ambient pollution data. Their uncertainties and/or strengths and limitations must be well understood, and they must be supported by science. When CRFs must be used for AQ management, expert solicitation is a helpful strategy for addressing these concerns (Cooke et al., 2007). Confounding and differential contact error among contaminants provide significant problems. There may be a link between a health endpoint and a specific pollution, among other things, because that pollutant serves as a signal of an unmeasured pollutant (gas or particle) or a combination of pollutants (Brook et al., 2007a; Goldberg, 2007).

For AQ risk management, CRFs based on direct connections between ambient observations of a variety of air pollutants, as measured by conventional monitoring networks, and acute and chronic consequences happening within the general population, are essential. The relevance of air pollution impacts to actual situations is further shown by demonstrating "real-world" linkages. In order to facilitate investigations on the health effects of both chronic and acute exposure, ambient measurements must be taken in the future. Creating CRFs for individual contaminants and combinations of pollutants that are suitable for risk management or cost-benefit analysis is one of the main issues when dealing with ambient pollution data. These must be backed up by evidence, and their uncertainties as well as their strengths and flaws must be well recognised. When using CRFs for AQ management, expert solicitation is a beneficial strategy for addressing these uncertainties, similar to AQ models (Cooke et al., 2007). Confounding and the numerous types of exposure error among contaminants provide significant problems. One reason there may be a link between a health endpoint and a specific pollutant is because it serves as a marker for an unmeasured pollutant (gas or particle) or a combination of pollutants (Brook et al., 2007a; Goldberg, 2007).

obtaining Representative Ambient Measurement

Ambient measures, no matter how precise they may be, cannot accurately capture the true exposure levels of an individual or the majority of a community. These metrics serve as a gauge for certain elements of the population's stress from air pollution. In actuality, there may be differences across pollutants and monitoring sites in the link between these indicators and the population's actual exposures. Critical problems are consequently site placements in relation to the population and the choice of the contaminants to assess at each site. Site requirements for acute exposure-effect research and chronic exposure-effect investigations are different. Although the latter is concerned in how exposure levels fluctuate over space, the former demands that the data properly represent temporal fluctuations in the population's exposure. This might include intraurban (disparities inside a big city) or interurban (differences between cities) differences (interurban). The optimal measurement data are seldom, if ever, accessible for both kinds of investigations due to technological and economical constraints. In order to use the metrics that are now available for health research or risk assessment, sacrifices must thus be made, and it is crucial to understand the implications of doing so.

When picking site locations or sites to be utilised for health research, it is crucial to consider the geographical composition of the sample, local physical characteristics (such as terrain and shorelines), and the current weather conditions. With this knowledge, the relationship between each set of data and the population will be more clearly understood, and population-weighted concentrations will be easier to determine. With the use of additional locations or specialised research, this viewpoint also aids in identifying and addressing monitoring network shortcomings.

There are 0.78, 0.77, 0.90, 0.96, and 0.84 for NO_2, O3, PM2.5, and PM10, respectively. The pair of sites with the lowest correlation, for normal monitoring networks, gives a solid indication of the lower bound of the representativeness of utilising a single site to predict daily changes in population exposure. Distance reduces the representativeness of measurements taken at one location to circumstances at another location. As a result, the representativeness of such a time series for population health research is improved by integrating the time series from a collection of sites spread over a city. The average and minimal correlations for NO2 between the site in downtown Toronto and the locations throughout the city are 0.83 and 0.75, respectively. When each site is compared to the average time series produced by combining the sites, these values rise to 0.89 and 0.86, respectively. The minimal correlation rises from 0.58 to 0.66 when the combined sites are used to represent the daily time series rather than simply the primary downtown site across a larger region that takes into account suburban sites. As shown in the correlations for Toronto, it is often the case that PM2.5 fluctuates most consistently throughout an area. Therefore, it is unlikely that the various PM chemical components would exhibit the same level of correlation as PM2.5 (i.e., total mass). For instance, OC is influenced by a variety of urban sources, such as cooking and traffic, and it may vary greatly in place and over time.

Before measures are utilised in health impact studies or before sites are added to or deleted from a network, it is crucial to evaluate intersite correlations. Examining the correlations sheds light on a time series' representativeness and helps explain why different contaminants have different impacts on human health as shown in time-series studies or in measurements of individual exposures. In multipollutant analyses, there is the potential to "transfer" the association to the pollutant that can be monitored at fixed sites with greater spatial sampling and/or with a stronger link to actual personal exposures, despite the fact that this source of exposure error should logically attenuate the significance of true health associations [25], [26].

Locations of monitoring sites may be improved, within certain bounds, to best reflect the population's potential exposure. When merging data from several sources, the data from each source may also be weighted based on how many people live in a certain area. Hence, measurements in locations with a larger surrounding population are given more weight. The intake fraction may be used to draw a perhaps greater connection to exposure (Marshall et al., 2003). This method is more suited for weighing the hazards of pollutant exposure brought on by emissions from various sources. As a result, in order to apply an intake fraction weighting to an ambient measurement, it is necessary to understand the sources that contributed to the observations as well as the relationships between the measurement, the source location, and indeed the population of interest, including estimates of pollutant concentrations in various microenvironments. The REHEX model (Winer et al., 1989; Fruin et al., 2001) and SHEDS (Burke et al., 2001) are two probabilistic exposure models that provide a method for determining the range of doses anticipated among the population from ambient concentrations. These models, among other things, need more precise spatial information on concentrations, which may be obtained either by interpolating the data or by employing AQ models.

Most recent exposure studies have focused mostly on PM2.5, and the findings typically demonstrate that daily personal exposure time series are connected with changes in outdoor levels. Yet, there is a lot of variation amongst people based on their daily activities, the common indoor microenvironments they frequent, and the indoor sources of PM2.5 in these places. Separating personal PM2.5 doses into particles of indoor and outdoor sources has also been attempted. It is widely recognised that intraurban differences in exposure are a significant signal to utilise in investigations of chronic exposure. With time, it will be impossible to run enough monitors, however. Studies of short-term saturation, in which several sites are run concurrently to define spatial patterns, may fill the gap. Since monitoring agencies use mobile platforms more often, technical advancements now make it possible to take measures that are even more complex. Nevertheless, measurements by themselves are unable to provide all the needed spatial data. The development of alternative information sources and/or a variety of spatial models, both statistical and physical, is thus becoming more and more crucial.

Tracking Progress

Monitoring networks' key goals include making sure that excellent AQ is maintained and monitoring how standards are being met. One or more, if not all, of the criterion pollutants are being monitored, and extensive data records have been and are still being gathered in the majority of mature networks. They also have many sites that are in standardised locations. They may so successfully accomplish this main goal. The best practise recommends maintaining a lengthy, uninterrupted record in order to investigate trends, in addition to choosing the appropriate areas and pollutants to assess. This is due to the possibility of minor, progressive AQ changes that are hidden by weather fluctuation. Trend analysis is hampered by inconsistent data, insufficiently sensitive measures, and underrepresentation in particular geographic regions.

Monitoring networks often concentrate on metropolitan regions, which results in a lack of rural data. For instance, despite its significance for comprehending regional O3 and PM2.5 and the effect nitrogen deposition might have on ecosystems, there are limited long-term trends on rural NOx levels globally. For determining how the expansion of urban areas' size and density (such as via sprawl) is affecting the nearby regional. Time-series length may not be as crucial for seeing subtle patterns as it is for identifying very big and sudden increases in emissions from a new policy or specialised action. Nevertheless, in this instance, accurate baseline measurements before to the emission reduction(s) as well as the continuation of these measurements after the reductions have been put into place are crucial.

AQ models may assist in guiding accountability-related monitoring operations. They may be used to replicate the size of the change at the locations where progress is being tracked. This may offer information on the need for additional measures at current sites or at new locations, as well as the measurement sensitivity needed given the predicted changes. These additional measurements, driven by models, would make it easier and quicker to show responsibility.

Use of Measurements in Model Development

Since more models are being run constantly for AQ forecasting, monitoring network data is becoming more critical in the assessment of models. The quality of the emissions data and the performance of the models may both be learned a lot from these new long-term modelled datasets. There are chances for diagnostic assessments as well, even though the network data seem to lend themselves more to operational evaluations of the model (see below). Whenever possible, the deployment of continuous or semicontinuous particle composition monitoring sensors should be taken into consideration since these data will allow for more thorough model assessments. The definition of the model's starting circumstances also depends heavily on network data. For this reason, fast data assimilation has made strides (Ménard and Robichaud, 2005). These assimilated datasets have a wide range of possible uses, as will be detailed below for the example of surface O3 concentrations.

The study of atmospheric processes (dynamical, chemical, and physical) and more thorough diagnostic model assessments eventually need very precise measurements, which can only be maintained for very brief field research. These studies can range greatly in their scope from small, institution-wide collaborations (EMEFS ICARTT; Dennis et al., 1993; Frost et al., 2006) to large, cross-institutional collaborations (Padro et al., 1993; Makar et al., 1998) focused on the study of a single process related to a single model module. The simplicity with which very detailed measurements may be carried out during field research is significantly increased by ongoing technology advancements.

Public Information

The process of AQ management depends on public education because when a When a significant majority determines that a matter is important, elected officials are more most likely to react. This may provide a chance for improvement in the condition of the air. Giving vulnerable population members regular, trustworthy, and clear AQ information also enables individuals to manage their own risk by lowering their own exposure. A typical communication method for public information is an AQI, which is produced from real-time readings or AQ forecasts to

provide an outlook. In areas or places where "poor air days" are common, the Generally speaking, the public is more aware with AQ concerns, at least in part because of the prominence of the AQI. In many nations, the AQI has a similar format, reporting AQ using descriptivephrases like "good," "moderate," "poor," "extremely poor," "unhealthy," etc. This strategy is simpler for the general public to comprehend and implement than reporting the real concentrations of pollutants. The AQI often aims to pinpoint the worst possible outcomes from the combination of contaminants being tested today and to explain the current AQ. the growing understanding of air pollution The Canadian Air Quality Health Indicator (AQHI) was created as a result of health consequences (Stieb et al., 2005). The AQHI's distinctive characteristic is that it is based on current epidemiology data. findings from all of Canada. Moreover, it takes into account various air contaminants at once, and in every instance, they all contribute to the index value.

Technical Issues in Establishing a Measurement Program

Measurement of air pollutants requires a firm commitment to an accepted quality standard as well as a strategy for the preservation and interpretation of data. Technology and knowledge are also constantly evolving. In order to increase the likelihood that the data will be accepted for a very long time to come, fresh measurements should aim to apply the most recent, approved techniques. A few measures with excellent quality will be more valuable than numerous measurements with poor quality assurance (QA), documentation, and interpretation. Activities for measuring AQ often fall into one of two categories:

1. Monitoring: A fundamental set of systematic measurements at carefully chosen locations that are kept up forever for trend analyses (i.e., to assess the efficacy of current policies), to determine whether or not a region is adhering to or exceeding an official AQ standard or guideline, and to identify emerging issues as soon as possible, which may involve ongoing environmental health studies (e.g., epidemiological studies).

2. Field studies: A relatively short period of time (2 years) during which more thorough or precise data are gathered in a region with a clearly defined boundary, at a single site, or for a specific population. For the creation of conceptual models, source-oriented models, more accurate source apportionment studies, and for comprehending the connection between emissions, ambient concentrations, and individual and/or population exposure, these data are crucial. AQ field investigations may also provide the exposure data used in a number of prospective health research.

CHAPTER - 17

QUALITY ASSURANCE

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Several measurements obtained with inadequate documentation, quality assurance (QA), and interpretation will be of less value than a limited number of high-quality measurements. A typical AQ measuring activity falls into one of two categories:

1. **Monitoring**: A fundamental set of systematic measurements made at carefully chosen locations and kept up-to-date indefinitely for trend analyses (i.e., to assess the efficacy of current policies), to check whether a region is meeting or exceeding an official AQ standard or guideline, and to spot emerging issues as soon as possible, which may involve ongoing environmental health studies (e.g., epidemiological studies).

2. **Field studies**: Measurements taken over a relatively brief time frame (2 years) that are more exact or precise, either in a particular site or for a specific population, or both. These facts are crucial to the creation of conceptual models, source-oriented modeling techniques, more accurate source apportionment studies, and the comprehension of the connections between emissions, ambient concentrations, and individual and/or population exposure. Other upcoming health research may also use AQ field investigations to get their exposure data.

QA is necessary in both the field and the lab for measurements that entail sample collection in the field followed by chemical or gravimetric analysis in the lab. The collecting of field blanks is one of the most significant QA procedures with regard to the field. At least 10% of the samples that are tested in the lab should be field blanks, regardless of the method used to collect the sample (e.g., filters, denuders, canisters, passive sorbants, traps, or cartridges). To make sure that the goals for data quality are maintained and/or modified, these techniques should be explicitly specified in the QA strategy and the produced data must be thoroughly reviewed.

Data Archiving and Reporting

It is crucial to save the final measurement data, together with the QA data and site information, for a long time. As averaging over longer time periods is likely to result in irrecoverable information loss, data should always be preserved at their original temporal resolution. Faster turnaround times might be anticipated to boost the value of the data, on the presumption that the more up-to-date the information, the more interested people there will be and the more impactful it will be to share what is being seen. For data access, there are many well-known national archives or portals, each with their unique requirements. National archives of standard monitoring data include the National Air Pollutant Surveillance Network (NAPS), which is maintained by Environment Canada's Environmental Technology, the AQS, which is the U.S. EPA's repository of ambient AQ data the Instituto Nacional de Ecologa's The European Theme Centre on Air and Climate Change's database AirBase lalso provides data from several European nations. NARSTO stores combined North American statistics from specialist field investigations.

To continue advancing our understanding of the consequences of pollutants on human health and the environment, as well as to evaluate the advantages of more specialised AQ management approaches, we need more precise geographical and temporal information on pollutant concentrations. Other sources of information employing a variety of spatial/temporal models, statistical or physical, are now required since direct measurement cannot offer this level of detail. In order to offer additional information, new techniques are being developed quickly that integrate (or "fuse" or "assimilate") model outputs with observed concentrations, including satellite-based data benefit from advancements in measuring technology, AQ modelling systems, and emission inventories that have been made as a consequence of scientific study over the last ten or more years.

The characterization of large-scale patterns throughout North America is currently being done continuously utilising data assimilation procedures that use real-time data and model output. The quantity and quality of information vary regionally and from one contaminant to another. O3 is now the most developed in North America, whereas protocols for PM2.5 are still being developed. O3 concentrations in the Great Lakes area of eastern North America. Concentrations are shown using the measure that serves as the foundation for the current Canadian and American standards.

The standard has a numerical value of 65 ppb in Canada and 75 ppb in the US. The figure's right panel is based on a mix of these data and the output from an extensive AQ model, while the left panel is a contoured map created using the concentrations measured at all of the available measurement locations. Overall, it is predicted that the concentrations in so many of the unmeasured regions in the right panel are more accurate than the estimations made using data interpolation alone because of how they were calculated. When model fields and observations are combined, the O3 pattern is created, and it has a lot more structure. This is a reflection of the locations of the precursor leaks, the topographical characteristics (which affect emissions and deposition), the atmospheric chemistry, and the prevailing weather patterns.

The values in the two panels agree at the majority of measurement places (the black dots in the left panel), as required by the procedure. Nevertheless, there are differences that indicate certain areas of the approach need to be improved, especially in the southern regions of the region (east Ohio and west Pennsylvania). There are significant point sources in the region's south, and the model's capacity to resolve near-source (subgrid) atmospheric processes is restricted. The version of the template interpolation shown here is primarily for data assimilation to help AQ forecasting, hence it only makes use of O3 data that is readily accessible in real time, which is the major reason for the disparity. As a result, fewer sites are included than were necessary to create the interpolated map in the left panel. The model's greater concentrations across Lakes Erie and Huron are among its most striking results. Low O3 deposition velocities over water are thought to be the cause of this, as well as accelerated production inside concentrated pockets or layers of O3 precursors that last owing to higher atmospheric stability over water.

Neighborhood scales account for a large portion of human exposure to ambient air pollution. Both the measurement networks and the present AQ models cannot resolve this. Moreover, it is doubtful that any of them would ever be able to resolve such scales. In order for AQ models to accurately anticipate at the 1–5 km resolution, new parameterization methods or separate emissions models will, at best, be created to tackle subgrid-scale characteristics. Research is still being done to determine the most effective way to utilise these models to forecast population exposure changes and associated uncertainties within these grid sizes so that the costs and advantages of small scale AQ risk management measures may be assessed.

Many methods are now being used to resolve smaller-scale concentration patterns (urban to neighbourhood size) for health investigations. They vary from small-scale dispersion models and/or combinations of both to interpolation of monitoring site data (Künzli et al., 2005; Jerrett et al., 2006) to exposure surrogates such distance-to-roadway and traffic counts (Hoek et al., 2002). As information on road networks is easily accessible, the local-scale hazards of interest have often been linked to traffic. Several attempts to estimate the exposure to ambient air pollutants have incorporated a larger spectrum of emission sources (Gram et al., 2003). Even while each of these initiatives improves spatial resolution, the majority of them do not have a strong connection to actual concentration measurements.

In comparison to the pattern created via interpolation, the small-scale spatial variability (i.e., neighbourhood size or better), produced by applying the LUR for all locations in a GIS database, seems to be more realistic with regard to the standard normal distribution of traffic (Jerrett et al., 2007). Future studies in this field will focus on methods to expand the pollutants that are taken into account and to add sequential data to the LUR maps. In the end, these methods for resolving extremely small-scale urban patterns should be able to integrate or "fuse" with larger-scale regional concentration patterns. It is reasonable to anticipate that ongoing developments in emission inventories, AQ modelling systems, in situ and alternative manner methodologies, and applications will advance this field of study and contribute to more efficient AQ management at all scales, from local to continental and even global.

The relationships between ambient pollutant concentrations, emissions of primary pollutants or their precursors, and various physiologically, ecologically, and optically significant characteristics are quantified using AQ models. They are the sole resource that can provide precise forecasts of future air concentration and deposition patterns based on potential emission levels and meteorological circumstances.

Accurate emission inventories are crucial for understanding how air pollutants affect ecosystem health and human health, for identifying the sources that need to be controlled to safeguard human and environmental health, and for assessing the success of emission reduction efforts. As the foundation for estimating the existing level of population health risk and setting priorities for reductions, AQ measurements are crucial for preserving public health. Also, they are essential for assessing the efficiency of AQ management measures and for modifying them if the anticipated results are not being obtained (i.e., by adaptive management.

Three of the most crucial instruments for AQ management are multipollutant emission inventories, ambient measurements, and AQ models. Each of these fields, as well as the analysis, interpretation, and integration of the data they supply, have made enormous strides over the last 20 years and continue to do so. Despite these developments, which include a better understanding of how low AQ affects people, our existing knowledge and instruments are at their limitations due to the demand to find the most cost-effective policies that benefit the public health the most. For instance, it is still very difficult to determine which highly specific control options will have the greatest positive impact on public health. These options may target particular chemical compounds found on fine particles, particular sources, or source sectors, or they may cause subtle changes in the overall chemical mix of the air (gases and particles). This problem is made more difficult by the lack of a thorough knowledge of exposure, health consequences, and the additive or synergistic effects of each component in the mixture. Future initiatives to enhance AQ, including comanagement of air pollutants and greenhouse gases, will need to take a wider perspective as scientists build a better knowledge of the environmental impacts and consequences of climate change on AQ.

CHAPTER - 18

ENVIRONMENTAL IMPACTS OF AIR POLLUTION

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In many regions of the world, ground-level ozone (O_3) is the most pervasive and phytotoxic pollutant that routinely exceeds the WHO's air quality standards (AQGs) for agricultural crops. It has been discovered that increased O3 levels reduce the productivity of various crop species, including wheat, rice, soybeans, and cotton. Such yield losses have been linked to changed carbon allocation (e.g., Grantz and Yang 2000), lower photosynthetic rate, and hastened leaf senescence. Moreover, O3 has been shown to cause apparent damage, which may, for example, lower the market value of leafy crops like spinach and lettuce; such damage often takes place after acute O3 exposures. A relatively small number of studies have also demonstrated that O3 has an impact on crop quality, including the nutritive quality of crop production and the nitrogen content of grains, tubers, etc. However, the direction of the effect—that is, whether quality is improved or degraded—varies between various quality aspects.

The first was the European Open Top Chamber (EOTC) Program (Jäger et al., 1992) and the second was the National Crop Loss Assessment Network (NCLAN), which used standardised techniques at sites across the United States (Heck et al., 1988). This research resulted in the creation of several O3 characterisation indicators that may sum up the seasonal O3 input (summarized in Mauzerall and Wang, 2001). According to Holland et al., economic losses for more than 20 arable crops in Europe are in the neighbourhood of $8 billion USD annually (2006). Adams et al. (1988) estimated losses of US$ 3 billion for nine distinct arable crop species in the United States. For China, South Korea, and Japan, Wang and Mauzerall (2004) assessed economic losses for wheat, rice, maize, and soybean at a total of US$5 billion.

These losses were indicated by percentage yield losses for the cereal crops of up to 9% and the soybean crop of 23-27% (a species recognised as very sensitive to O_3). The size of these losses was consistent with related research by Aunan et al. (2000), which indicated current yield losses of between 1% and 3% for a few Chinese grains (although this study only measured productivity rather than economic damage). Emberson et al. (2009) collected and compared dose-response data for Asian commodities (wheat, rice, and legumes) with dose-response correlations generated in North America in an initial effort to evaluate the importance of this deficiency. The findings indicated that Asian cultivars of wheat and rice are significantly more sensitive to O_3 than their North American equivalents; as a result, the studies by Wang and Mauzerall (2004) and Aunan et al. (2000) may have significantly underestimated the effect O_3 has on crop productivity in Asia. Nevertheless, the modelling studies that were carried out using North American and European dose-response relationships should still be viewed as offering useful data on the relative spatial magnitude of risk across regions and giving an indication of the potential destruction that is likely to occur based on current knowledge.

Given the anticipated trends for future O_3 concentrations, it is even more critical to evaluate the possible harm that O3 poses to agricultural output. According to Prather et al. (2003), adopting the IPCC 2001 A2x SRES global emission scenarios (Nakic'enovic and Swart, 2000),the expected worldwide rise in O3 concentration over the next 100 years. South and South East Asia, southern Africa, and other locations may be anticipated to see rises in ground-level O3 in the future, according to this figure, which utilises forecasts for 2100 and one of the most severe Intergovernmental Panel on Climate Change (IPCC) global emission scenarios. With projections of increases in mean surface O3 concentrations of 7.2 ppb between 2000 and 2030, modelling studies carried out over a shorter time frame by Dentener et al. (2006) that used current legislation emission scenarios support the identification of South Asia as the region most likely to suffer the largest increases in O3 concentration. These studies strongly suggest that conditions may significantly worsen in the near future.

By collecting data from 10 different nations, the RAPIDC Crops Project set out to determine the existing "state of knowledge" about the effects of air pollution on both agricultural productivity and forest health. Sulfur dioxide (SO_2), nitrogen oxides (NOx), ground-level ozone (O_3), suspended particulate matter (SPM), and hydrogen fluorides were among the air contaminants examined (HF). Several observational and experimental methods, including as the field recording of observable damage, transect studies along pollution gradients, chemical protectant investigations, and filtration and controlled fumigation experiments, have all been used to illustrate the consequences of air pollution. The data gathered from the emerging nations showed that certain nations (such as China and India) were substantially better advanced in terms of compiling sizable datasets from which the effects of air pollution could be evaluated. Yet, the bulk of the air pollution impact assessment work completed to date examined impacts brought on by SO_2 (representing more than half of all studies), with O_3 and SPM evaluations together accounting for the majority of the effort.

remaining research. (2003) and Emberson et al. (2003) both published the findings of these experiments (2001). Among the main significant crops in South and South East Asia, highlights some of the relevant findings regarding the effects of ambient O_3 concentration on yield losses (i.e., data are solely aggregated from filtration, ethylenediurea (EDU), and transect studies). We have not included research estimating agricultural yield loss at ambient O_3 concentrations in Southern Africa since we are not aware of any such studies. As the O3 concentration to which the crop will be exposed fluctuates annually, lso includes information on the crop-growing seasons (e.g., in South Asia, depressions in O_3 concentrations occur during the monsoon period because of reduced photochemical activity). In order to determine which crops are most likely to be at danger from O_3 contamination, this knowledge is essential.

It was also recognised that several perennial crop species, including peach, apple, mango, guava, and tea, were significant and were to be taken into account in future research. Yield, yield components, harvest index, and nutrient content (including elements like protein/nitrogen as well as the concentration of sugars and specific acids) are likely to be effect factors of relevance for these kinds of crops. This research came to the important conclusion that although many observational and experimental techniques existed and had been used to evaluate the effects of air pollution, they had never been employed in accordance with any form of established procedure. Because of this, it was difficult to integrate the data to create a sizable dataset from which one would be able to extrapolate the dose-response correlations required to carry out regional-scale risk assessments. The work done under RAPIDC was intended to address this issue, and after determining the present state of knowledge on the effects of air pollution, focus shifted to the creation of infrastructures and methodologies to attempt to close knowledge gaps.

The APCEN Network

An Air Pollution Crop Effect Network (APCEN) was created in 2002 to aid in the accomplishment of these objectives (http://www.sei.se/apcen/index.html). This network of experts on the impacts of air pollution sought to improve coordination between observational and investigative research as well as efficient communication amongst air pollution scientists working in various parts of the globe. With the purpose of enabling the use of standardised techniques for air pollution effect assessments, APCEN has created experimental procedures that are especially intended for use in developing nation areas. Techniques for analysing the socioeconomic effects of air pollution were also taken into consideration. The APCEN network gathers often at international workshop meetings to develop and coordinate techniques for evaluating the effects of air pollution on agricultural yields and to discuss the best ways to inform decision-makers about the results of research. More than 80 air pollution impacts experts from over 30 countries now make up the APCEN network, mostly from Asia, reflecting the shifting geographical priorities of the RAPIDC Crops Initiative.

The APCEN network's main responsibility for the RAPIDC Crops Project has been to provide technical and scientific assistance for risk assessments carried out across South Asia and southern Africa. In this regard, APCEN has created and tested experimental and observational methods, as well as provided guidance on the selection and use of suitable AQGs for use in regional risk assessments, to increase its ability to carry out such risk assessments. It is essential that the development of the network role be fully taken into consideration in terms of the goals and research interests of related multilateral forums in order to ensure the best use of APCEN resources to provide information that can be used to drive policy in the most effective manner. Specifically, this would include fortifying connections with the Malé Declaration nations of South Asia's continuing policy processes as well as with the developing policy processes in the southern African countries, the Air Pollution Information Network for Africa (APINA). Since 1998, these two science-to-policy networks have been operating with the goal of successfully integrating the most recent scientific research on the effects of air pollution (see Hicks et al., 2001). The South Asia Cooperative Environ Programme (SACEP) Council of Ministers endorsed the Malé Declaration in 1998, and the nations are now getting ready to explore the structure of a regional Convention or other instruments to address their air pollution issues. The Lusaka Accord (2008)—the regional policy framework on air pollution for the Southern African Development Community (SADC)—has been proposed to SADC in southern Africa by APINA for potential acceptance by the SADC

Ministers of Environment and Sustainable Development. Significantly, these policy-making procedures acknowledge the work of APCEN.

Provisional Risk Assessment Modeling and Mapping

Here, interpolated monitoring data or atmospheric transfer models may be used to create regionally mapped concentration data. An accurate emission inventory, weather information, and an adequate atmospheric transport model are required for the simulation of concentrations. Receptor information is needed to illustrate the location of the species, ideally as a map with an accompanying pertinent database, after concentrations have been defined in a way that is acceptable to estimate effects on crops. This data may be used to create maps that show areas where concentrations are higher than the critical level. Using the MATCH model's results, a tentative risk assessment for South Asia was conducted (Engardt, 2008). A reanalysis of meteorological data from the European Centre for Medium-Range Weather Forecasting (ECMWF) is what drives this off-line Eulerian dispersion model. Streets et al. (2003) provided estimates for anthropogenic emissions of SOx, NOx, NHx, nonmethane organic volatile compounds (NMVOC), and CO; Guenther et al. provided estimates for anthropogenic emissions of biogenic volatile organic compounds (VOC) (1995). Based on Simpson et al., MATCH employs a photochemical system with around 60 chemical species (1993). The vertical resolution in MATCH grows from 20 m at the surface to 400 m at 5 km above the waves, with a horizontal resolution of 50 km.6

The results from the MATCH model were used to construct the tentative risk assessment for South Asia. The European Centre for Medium-Range Weather Forecasts (ECMWF) > reanalysis is the source of the meteorological data used to fuel this off-line Eulerian dispersion model. Estimates of carbon activities of SOx, NOx, NHx, nonmethane volatile organic compounds (NMVOC), and CO are obtained from Streets et al. (2003), whereas estimates of anthropogenic emissions of biogenic volatile organic compounds (VOC) are provided from Guenther et al (1995). Using a photochemical method based on Simpson et al., MATCH employs around 60 chemical species (1993). MATCH has a horizontal resolution of 50 km and a vertical resolution that rises from 20 m at the surface to 400 m at a height of 5 km above the waves.

Provisional Risk Assessment for South East Asia

The results from the Model-3 Community Multi-scale Air Quality (CMAQ) model were used to construct the tentative risk assessment for South East Asia. The United States Environmental Protection Agency (US EPA) developed CMAQ, or "one atmosphere," a Eulerian-type model to simulate tropospheric O3 and a variety of other atmospheric phenomena while taking into account the intricate interactions between atmospheric pollutants at both regional and urban scales (Byun and Ching, 1999). The Fifth-Generation Pennsylvania Community College Center for Atmospheric Research (PSU/NCAR) Mesoscale Meteorological Model produced the meteorological fields required as CMAQ's input.

Average area GDP growth rates were reported by Nghiem and Oanh (2008). Guenther et al. provided the NOx and VOC biogenic pollution data (1995). With revised reaction rates, the Carbon Bond Process IV (Gery et al., 1989) was utilised (Atkinson et al., 1997). The horizontal grid area for CMAQ and MM5 is the same at 56 km (0.5°). Vertically, the areas range from mean sea level (0 m) to roughly 16,000 m for both the Continental Southeast Asia (CSEA) and the centre region of Thailand (CENTHAI) models. The vertical precision of these two models increases from 38 m close to the ground to nearly 2 and 3 km at the summit of the domain, respectively. The MM5 has 30 vertical levels, while the CMAQ has 15. Before being used to predict hourly O3 concentration fields, the model system's performance was successfully assessed on a few past events (Nghiem and Oanh, 2008).

Van Tienhoven et al. (2006) provide a more thorough description of the preliminary risk assessment that was conducted for southern Africa in an effort to determine whether surface O3 concentrations could endanger agricultural yield and way of life in the area. This simulation research made use of near-surface O3 amounts produced by the Comprehensive Air Quality Model with Extensions (CAMx) (Zunckel et al., 2006). (ENVIRON, 2006). The southern African nations of Botswana, Mozambique, South Africa, Zambia, and Zimbabwe were included in the modelling area. The modelling was based on geographically resolved emissions of CO, SO2, NOx, and total hydrocarbons from human-caused activities (industry, transportation, and household combustion) as well as biogenic emissions of VOCs that mirrored hourly and yearly changes (Fleming and van der Merwe, 2002). (Zunckel et al., 2006). Since biomass-burning pollutants were deemed insignificant after the start of the summer rainfall, they were not taken into account during the simulation period from October to April.

The study focused on the common agricultural product maize (Zea mays L.), which has been found to be relatively susceptible to O_3 and is essential for both industrial and communal cultivation in southern Africa. The actual sowing and harvesting times will differ depending on the temperature and, consequently, the position throughout the area, but the corn growth season is typically thought to last from October to April. Five days per month for a total of seven months were used to execute the CAMx model. In order to determine the possibility for harm, the AOT40 O3 concentrations were estimated using the output O_3 concentrations (under the assumption that the five-day span was indicative of the full month). When analysing the findings of the risk evaluation, it should be kept in mind that, similar to rice, maize is thought to be less susceptible to O_3 than wheat.

The use of the European AOT40 concentration-based risk assessment technique is perhaps the most glaring example of a flaw that is evident in all three of the preliminary risk assessments that are provided here. The crucial level of 3000 ppb.h is based on wheat types cultivated in Europe, and it is debatable how indicative of danger this level is for cereals produced in Asia and Africa. Since agricultural tracking of O_3 concentrations in some regions of Asia and southern Africa is either highly restricted or unattainable, these studies also require a presumed precision in the photo-oxidant modelling. This makes it difficult to evaluate the modelled concentrations. Given that O_3 episodes are linked to specific meteorological conditions (such as sunshine hours, temperature, the predominant wind direction from precursor pollutant sources, etc.) and, therefore, will typically have a high variability from week to week, the extrapolation of the five-day O_3 concentrations is another significant source of uncertainty for the risk assessment for southern Africa. Therefore, these studies should be seen as giving a sign of possible danger, but additional research is immediately required to better our knowledge of the possibility of agricultural harm across these areas. Modeling-based risk evaluations are helpful, but it's important to develop the ability to conduct studies to see if the effects on products on the ground are as anticipated by the modelling studies. To illustrate the scope and spatial spread of agricultural harm from O3, straightforward field studies are a helpful method.

Monitoring and Chemical Protectant Studies in South Asia and Southern Africa

Although there is a lot of experimental data showing that O3 affects agricultural production declines throughout Asia (Emberson et al., 2003), these studies have a history of being conducted independently of one another. Due to the lack of standardisation in the experimental work, it has been challenging to combine data from various studies to derive reliable dose-response relationships. As a result, a planned programme of work needs to be created so that scientific studies that have followed established procedures can yield findings that are similar.

APCEN is creating and testing a variety of methods for evaluating the dangers that various air contaminants cause to plants. To "ground truth" the preliminary modeling-based risk evaluations and show the true effects of O_3 on agricultural growth and output, two techniques were chosen as the top priorities for development. These techniques included (i) a clover clone biomonitoring technique that tracked visual damage and biomass loss and (ii) an EDU chemical protectant technique that enabled for the measurement of production losses for specific crops. Both techniques evaluate harm at atmospheric O_3 levels.

The Clover Clone Biomonitoring Method

The International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) of the United Nations Economic Commission for Europe (UNECE) first developed the clover clone method in the humid subtropical climate of North Carolina, USA, and it has been widely used since 1996 in Europe and North America. The technique employs O_3-sensitive and O_3-resistant white clover genotypes (Trifolium repens cv. Regal) and is based on the idea that the difference in foliar damage and biomass ratio between the O_3-sensitive (NC-S) and O_3-resistant (NC-R) clover genetic makeups can be directly correlated to the prevalent O3 concentrations during the exposure period. The current protocol was tested during the 2005–2006 growing season at a study site at the North-West University in Potchefstroom, South Africa (Krüger, G.H.J., Personal Communication) and during the 2006–2007 growing season at a periurban site near Lahore in Pakistan.

The clover biomonitoring protocol's effective testing indicated that it was "fit for purpose" for circumstances in southern Africa and South Asia. As a result, the technique was used at a few chosen locations throughout southern Africa and South Asia during the 2007–2008 growth season. The first findings from South Asia indicated that the sensitive clover genotype suffers yield losses in the range of 10–20% when compared to the robust clover genotype, showing that atmospheric O3 amounts in these areas are capable of harming local plants. It was determined that in the future, the plants would need to be established over a full growing season that they were suitable for use as biomonitors. However, difficulties with the establishment of the clover plants at the various sites across both regions made it difficult to compare the results in a reliable manner.

Using experimental experiments conducted in South Africa and India, APCEN created EDU procedures for a number of plants, including mung bean (Vigna radiata L.), wheat (Triticum aestivum L.), spinach (Spinacea oleracea L.), potato (Solanum tuberosum L.), and pea (Pisum sativa). These species were chosen because they are economically significant in either South Asia or southern Africa and are thought to be O3 sensitive (Agrawal, S.B., Personal Correspondence; Agrawal et al., 2005; cf. Tiwari et al., 2005). During the growth seasons of 2006–2007 and 2007–2008, this procedure for mung bean was applied at a few chosen locations throughout South Asia.

There are still a lot of challenges to be overcome in the future, such as continuing these studies to collect data over several years and applying the standardised methods to other regions (like South East Asia) where O_3 is a potential threat now or in the future. Despite the methods established by this work that enable increased understanding of the effects of air pollution today in these regions, there are still a lot of obstacles to overcome. The viability of South Asia's per-capita grain output is somewhat unclear. The Indo-Gangetic Plains of South Asia profited from the Green Revolution of the 1960s. In just three decades, South Asian farmers were able to increase wheat output by almost five times and double rice production by using better wheat and rice types, irrigation, and larger fertiliser dosages. But the region beneath.

Evidence indicates that increases in grain harvests have started to slow down in many high-potential farming regions, with differences in patterns between South Asian nations (Timsina and Connor, 2001). This decline will have been influenced by a number of elements, including soil fertiliser extraction, declining organic matter levels, rising salt, declining water tables, and the growth of plant, disease, and insect populations. It would appear that O_3 pollution may very well be an extra and major burden on agroecosystems given the size and breadth of production declines observed for important commodities across the South Asian area in this and another research. Given the region's challenge to provide lasting yield rises to offset decreased per head area gathered, a thorough knowledge of the relative significance of all stressors confronting current and future agricultural production in the South Asian areas is essential.

Due to a number of variables, such as land deterioration, soil fertiliser constraints, climate appropriateness, and stresses from development, access to rich areas for cultivation in southern Africa is already extremely constrained. A significant element that will affect how suitable property is for various purposes is climate change. The majority of the few O3 concentration measurements recorded in southern Africa consistently surpass 40 ppb (the cut-off concentration above which O_3 accumulation causes damage to vegetation). Depending on the emission scenario used, annual mean surface O_3 concentrations for South Asia and southern Africa could range from -5.9 to +11.8 ppb for South Asia and from -2.5 to +7 ppb for southern Africa by 2030, according to global modelling of ground-level O3 concentrations. The potential rises in mean yearly norms would result in significantly higher average amounts during the growth season, when the environmental factors (specifically temperature and sun energy) are favouring the atmospheric production of O3. Therefore, it appears highly probable that O_3 concentrations, which are already at levels that can result in crop and output declines across many regions of South Asia and southern Africa, will deteriorate over the course of the next 20 to 50 years. Therefore, it would be wise to take this contaminant into account when conducting future stu to encourage unity of thought dy to determine how various stressors affect agricultural output in Southern Africa and Asia.

APCEN is now associated with the GAP Forum, a project of the International Union of Air Pollution Prevention Associations (IUAPPA) and SEI, which, since 2004, has supported collaboration and the development of common practise among scientific and policy networks around the world, primarily focused on the reduction of air pollution at the regional level, in order to promote convergence of approaches for assessing impacts of these multiple stresses on agriculture across the globe. The use of the APCEN network to increase knowledge of the danger that tropospheric O3 (and other pertinent air contaminants) pose to agricultural production and quality is suggested under the GAP Forum. Additionally, it will be crucial to broaden this research to include efforts to identify the social groups (such as urban and periurban areas) and agricultural techniques (such as subsistence farming and small- and large-scale agroforestry) that may be especially susceptible to the effects of air pollution damage on crops.

Future analyses of the effects of O3 on crops should ideally take the effects of climate change into account and attempt to engage experts in response strategies. To debate probable combined effects, steps to lessen end users' susceptibility, national risk evaluations, and policy choices to lessen the danger from this environmental issue, important decision-makers from governments should ideally join together. In many developing regions where there is scepticism about climate change policies but where the significance of reducing air pollution is understood, the opportunity for cobenefits for air pollution and climate change in emission reduction policy is of particular importance. However, the majority of the work on cobenefits has been done with goals and views from the industrialised world.

CHAPTER - 19

IMPACTS OF AIR POLLUTION ON THE ECOSYSTEM AND HUMAN HEALTH

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Nowadays, there is widespread interest in the environmental viability of human activity, which goes hand in hand with current economic and societal concerns. A market is not a fully autonomous entity Contrarily, social systems, which seem to be themselves subdivisions of environmental systems, are subsystems of economic systems (Giddings et al., 2002). On a global stage, every economic system is a component of a social system, which is a component of an environmental system. As a result, it is impossible to maintain human health and wellbeing while ignoring the condition of environments. As opposed to this, human health starts and concludes with the wellbeing of the local environments (Waltner-Towes, 2004), after which societal harmony and a socially conscious economy come into play (Scholtens, 2005). Environmental viability and wellness are essential to providing sustainable health treatment. Maintaining ecological health equates to maintaining our own health, which lowers our chance of illness and lowers the cost of medical care.

Global biogeochemical cycles connect the lithosphere, hydrosphere, and atmosphere through natural networks to the Earth's ecosystems.Natural energy flows and biological cycles are impacted by human economic activity, which in turn places different pressures on the behaviour and health of ecosystems.

In ecosystems, stress is a condition that shows up as shifts in the energetics of the system, the movement of nutrients, and the composition and behaviour of native species and groups. Human action can be seen as a "stressor" in this situation, which is an activity that has a "detrimental or disorganizing effect" (Odum, 1985; Rapport et al., 1985). The gravity flow of materials from land to water and from the sky to land and water is the primary mechanism by which terrestrial and marine environments are connected. Anthropogenic contamination is accelerated by this overall dynamic. Through natural networks comprising the atmosphere, the hydrosphere, and the lithosphere, the Earth's habitats are connected by global biogeochemical cycles.

Ecosystem dynamics and health are subjected to a variety of stressors as a result of human economic activity's impact on natural energy flows and biological cycles. In ecosystems, stress manifests as a condition that alters the energetics of the system, how nutrients are cycled, and how native species and groups are organised and operate. According to Odum (1985; Rapport et al., 1985), human action can be viewed in this context as a "stressor," or an activity with "detrimental or disorganizing effect." The gravity flow of materials from the land to the water and from the sky to the land and the water to the land connects terrestrial and marine environments. Anthropogenic contamination is hastening due to this general dynamic.

The public is now interested in a variety of contaminants. In essence, the past phases and trends of the growth of human society and business appear to be followed by pollution. Regarding the connection between economic action and the climate and human health, air pollution was at the centre of science and societal worries.

The argument over the Environmental Kuznets Curve (EKC) theory is arguably the most in-depth scholarly discussion that is also the most important to the general audience and decision-makers. The EKC theory states that up until a tipping point, pollution severity (and the loss of natural resources) rises with social growth (often stated in terms of per individual revenue), and then they start to fall. On the basis of newly obtainable statistics on emissions for SO_2, NO_2, and CO_2, some instances of EKC-type correlations in a number of European nations. An EKC-type trend can be seen by choosing a few nations that reflect various growth (industrialization) phases. The preindustrial era of growth is approximately represented by Hungary in this instance, the industrial stage by Greece and Spain, the postindustrial stage by the United Kingdom and Germany. When these data are taken into account, an inverted-U connection is easier to see with SO_2 and NO_2 data than with CO_2 data. Depending on the adjusted solution, an N-shaped association can also be found.

The desire for a healthy environment and pressure for the implementation of less harmful practises and technologies also increase as people start to break free from fundamental economic limitations (Barbier, 2005). In summary, the human development index (HDI), an overall indicator of economic prosperity, physical and mental health, and educational attainment, describes how rapidly environmental deterioration is related to general human development. When taken to its logical conclusion, the EKC theory contends that we shouldn't worry too much about the climate because environmental issues will eventually be resolved organically as a result of continued economic growth. Even the idea that wealth is the only way to solve environmental issues has been floated, and that any restrictions placed on economic expansion undermine environmental protection efforts.

because they don't use accounts of actual environments, only specific contaminants, or even basic pollution markers. For instance, the fact that SO_2 air pollution is declining in wealthy nations does not necessarily indicate that the issue has been resolved; it could simply indicate that the harmful industries that once drove these nations' budgets have been moved to impoverished nations, like Asia. In fact, there is an increase in the tendency of worldwide SO2 production The present climate shifts are anticipated to significantly alter the patterns of air movement, which could result in the spread of SO2 throughout the entire planet.

Environmentally conscious development Natural capital is irreplaceable

Only the characteristics of natural systems, such as their frequently irregular behaviour and uncertain, irrevocable processes, can be used to value natural resources. The entire capital supply is comprised of natural capital, tangible capital, and human capital Natural capital refers to a wide range of ecological products and services that serve as the cornerstone for the continued growth of both human and physical capital. These advantages result from each ecosystem's unique and general characteristics. These advantages are almost always necessary for human health and prosperity as a whole. Key biogeochemical cycle processes, such as biomass production and biomass decomposition by specialised creatures known as primary producers and decomposers, respectively, are necessary for the functions and benefits provided by ecosystems. Invertebrate detritivores break down waste into tiny fragments that can be chemically reduced further, and bacterial and fungus decomposers convert the fragments into inorganic compounds like ammonia, phosphate, water, and carbon dioxide (CO_2). Plant chemistry and output, as well as the biomass and population makeup of detritivores, are effectively linked to animals through these plants (consumers). The purity of the natural makeup of the microbial, animal, and plant communities is a requirement for the protection of all ecosystem structure and function because species and functional categories of creatures are interconnected. Some argue that increases in people and physical capital should be able to make up most, if not all, of the loss of natural capital. However, compensations—if any exist—can only be considered in reference to specific natural capital (thresholds) after which they cease to be effective. However, due to the intricacy of natural systems, especially due to the naturally chaotic dynamics of ecosystems, as well as due to their past nature, such crucial capital cannot be found (Ekins, 2003). Given this unique intricacy, it is difficult to imagine—to put it mildly—that knowledge and technology will ever be able to make up for declines in natural capital.The worst course of action in this case would be to destroy natural wealth, so it should be avoided.

Environmentally conscious development

Three main factors primarily contribute to environmental degradation by humans: the size of the human population supported by local ecosystems, average individual consumption, and inappropriate technology use. The ecosystem carrying capacity and the ecological footprint of humans are two interconnected ecological economics concepts that capture the overall relationship between humans and ecosystems. Support ecosystems allow for a certain amount of wealth extraction above their own regenerative capacity, depending on bioproductivity and other biological parameters: renewable resources. Each ecosystem has a unique "carrying capacity" that may be higher or lower. The "ecological footprint" is a measurement of the basic factors that influence how human activity affects ecosystems.

Common high-income cities utilise a vast hinterland's productive and assimilative potential, and their ecological footprint is hundreds of times larger than the areas they actually occupy (Folke et al., 1997). According to Barrett and Simmons (2003), the ecological footprint of highly inhabited and industrialised nations may cover an area that is more than several times the size of the country's national land, such as three times the UK. Such figures refute the notion that environmental issues are being resolved as nations become wealthier. On the other hand, national economies in industrialised nations appear to have substantial ecological impacts, limited freedom in reducing them, and unevenly dispersed effects, including a genuine influence on the support ecosystems of other nations.

CO_2 emissions and climate change: Risks to ecosystems and human health and welfare

Probably the amplest effects of human activities on the environment are climate changes. These appear to be caused mainly by industrial emissions of CO_2, but also by emissions of CH_4, N_2O, and other GHGs constituting “aggregate GHG” Climate change alters a variety of natural systems' functional processes, frequently putting the survival of more delicate environments and the financial security of human communities that rely on them in peril. Climate shifts may have important feedback effects with ecosystems, essentially because of consequences on energy fluxes in the ecosystems: food networks and food webs created by biomass producers, biomass users, and decomposers. For instance, the breakdown of plant litter (along with root litter), a crucial process that is thought to account for about 70% of the total yearly carbon flow (Reich and Schlesinger, 1992), is impacted by global warming. These effects are short-term mediated by the physical characteristics of soils (such as temperature and humidity), and long-term mediated by waste quality as a result of changes in plant community makeup brought on by climate change.

Communities must adapt and species must move in order to maintain their ability to adapt and to meet the best physiological and ecological needs as a result of local climate warming and changes in precipitation regimes. According to global analyses, species range boundaries are moving towards the poles at a rate of 6.1 km per decade on average. Such pressures are especially important for specialised species, such as stenotherm species, which have limited tolerances to temperature. However, the species must first get past two other significant challenges. The first is that species might not have enough time to adapt to the changing climate because of the vast GHG emissions that have occurred in a comparatively brief period of time. Second, because the majority of the natural habitats have been destroyed due to conversion to agriculture and other uses, even if species could theoretically relocate quickly, they would not have enough moving corridors between the current and the proposed geographic ranges.

Some regions of the planet are more vulnerable to suffering from climate change. High-latitude regions, for instance, are particularly vulnerable to global warming. High-altitude ecosystems and arctic and subarctic tundra ecosystems are the best indicators of potential impacts of global warming on Earth's ecosystems Since biological material created during the northern summer cannot decompose due to the frigid winter temps, permafrost areas are known to act as CO2 sources. Recently, researchers have started to investigate the possibility that global warming could cause positive feedback in which vast stores of organic matter in tundra soils start to decompose (given enough moisture) and act like carbon sources that increase GHG emissions and global warming. Additionally, it is important to note that plants and vegetation in all biogeographic provinces are both CO_2 sources and sinks (through photosynthesis) (through respiration). The equilibrium of CO_2 emission/fixation may change as worldwide and local mean temps rise, though not definitely in favour of CO_2 fixation.

High CO_2 amounts and global warming determine changes in the composition of plant communities, either directly or indirectly, and hence decide fundamental changes in the biological processes governing those ecosystems. For example, environmental shifts at high altitudes have effects on both the sexual ecology of blooming plants and the flow of nutrients. Due to the multiplicity and interdependence of these effects, comparatively abrupt environmental shifts will have unexpected and upsetting impacts on ecological functioning. The altering epidemiological pattern in both ecosystems and human populations is a significant concern associated with air pollution-driven climate changes.

The host-pathogen relationship may change as a result of climate change, favouring the spread of pests that low temperatures would normally keep under control. For instance, bug pests could multiply more frequently each year, causing extensive harm to products and woodlands that are already directly impacted by climate change. This would support the population decreases and extinctions of numerous plant and animal species, with severe repercussions for the output and security of ecosystems (Rossignol et al., 2006). There is evidence that the dynamics of host-parasite systems have already started to alter in Northern regions, primarily due to impacts on parasite spread. Esty et al. (2005) proposed an environmental sustainability index (ESI), which has the backing of a group headed by the Yale Center for Environmental Law and Policy. ESI assigns a ranking to nations based on how well they manage the environment. Scores are based on five main factors: the current health of natural systems, the extent of anthropogenic stresses on the environment, the degree of human and societal vulnerability to environmental disturbances affecting human well-being, the capacity of society and institutions to respond to environmental challenges, and the capacity to address environmental issues on a global scale. It is important to note that no country performs particularly well across the five dimensions, indicating that there is much that all nations can learn from one another's experiences. The fact that all of the top-scoring nations have strong natural endowments and low population densities is another intriguing finding of the ESI team. This means that those high calculated standards still need to be proven with challenges of greater magnitude in the future, like upcoming environmental changes related to climate.

Meteorological anomalies are connected to a number of primary factors. Classical heat-related diseases include skin rashes, heat exhaustion, heat stroke, heat cramps, heat lethargy, and fainting (World Health Office Europe, 2004). The vascular system dilates at greater body temps brought on by inadequate air control in heated air, which lowers blood pressure and oxygen delivery to the brain and results in heat syncope. Dehydration and a lack of muscular exercise both hasten blood pressure declines. Exercise raises blood pressure and avoids fainting, which further raises body temperature and causes heat fatigue. If the core temperature exceeds 40.5°C, as it might with vigorous exercise in the summer

Severe cognitive disability, such as respiratory distress syndrome, renal and liver failure, and disseminated intravascular coagulation, are among the complications of heat stroke. People who are less physically fit—like some old people—have reduced thermal endurance. In their situation, heat-related sickness may even develop with little to no muscular exertion. Predisposing factors for thermal illness include a variety of sporadic circumstances that are typically not thought to pose a significant health risk, such as poor acclimatisation, intestinal issues, the use of diuretics, alcohol abuse, the use of medications that affect the body's temperature regulation systems, obesity, fatigue, lack of sleep, prolonged and intense exercise, and garments.

Cities elevate the local temperature, a process known as the "urban heat island" effect, making climate change and heat-related diseases more common in metropolitan areas. With an increase in population and construction density, the temperature differential between a city and its surroundings rises, going from up to 2.5°C for villages with 1,000 residents to 12°C for American cities with one million residents. Numerous factors connected to the alteration of nearby natural ecosystems contribute to this effect, including (WHOE, 2004) increased radiation exposure, reduced radiant heat loss in urban vegetation, lower wind speeds (meaning lower rates of heat dissipation), changes to the water balance, and increased domestic and industrial heat production (including waste heat and emission of air pollutants). In towns, the health duress brought on by extreme heat waves is not eased at night, increasing the number of casualties.

The rates of harm and mortality rise as severe events like cyclones and floods occur more frequently and with greater intensity. A word of warning is needed, though, as the exact relationship between climate change and storms is still up for discussion (Pielke Sr. et al., 2005). Additionally, climate change should not be used as a justification for fatalities brought on by poor disaster management on the part of humans (SR, 2007).

Ecosystem duress and the resulting reduction or elimination of ecological advantages are related to indirect causes. The following are some instances of how changes to environmental processes and occurrences can have an impact on human wellbeing. Vincent suggested a measure of societal susceptibility to climate change (2004). Social fragility is defined in terms of both risk exposure and social risk tolerance. This social vulnerability index (SVI), which specifically considers African nations, is the result of the weighted averaging of five composite subindices, including economic well-being and stability (20%), demographic structure (20%), institutional stability and strength of public infrastructure (40%) and global interconnectivity (10%). It also includes natural resource dependence (particularly water availability) at 10%. SVI should be used in combination with the proper physiological vulnerability markers. The primary purposes of SVI are to direct efforts towards developing adaptive management capability in those nations that are most in need and to do so in an organised and effective way (Vincent, 2004). It goes without saying that using SVI in addition to the HDI of the United Nations Development Plan that was previously stated is recommended.

Since at least a few decades ago, reactive pollutants like chlorinated fluorocarbons (CFCs) and other organic compounds have been released into the atmosphere, causing another significant problem: stratospheric ozone is being broken down, causing the ozone layer of the stratosphere to become thinner, allowing more ultraviolet (UV) radiation to reach the Earth's surface (Herman et al., 1996). In the end, human air pollution exposes creatures to higher natural UV radiation levels. Including the utilisation of farming, pasture, and woodland resources, this has an impact on biological processes and ecological working. Production of active oxygen species and free radicals, photochemical alterations to DNA and proteins, and incomplete photosynthetic suppression are some direct impacts on specific animals, including people. However, many other harmful effects of UV rays are secondary, extremely complicated, and have significant repercussions for both human wellbeing and ecological security.

The Montreal Protocol on Substances that Deplete the Ozone Layer, which was first adopted in 1987 and has since been revised and/or amended numerous times, is currently in place and is administered by the Ozone Secretariat of the United Nations Environment Programme (UNEP). The Vienna Convention for the Preservation of the Ozone Layer served as the framework for the Protocol's negotiations. ODSs began to be eased out and substituted with other drugs as part of the Montreal Protocol. Through a system known as the Global Fund for the Implementation of the

Montreal Protocol (http://www.multilateralfund.org), poor nations have received funding support since 1991 to conform with the Montreal Protocol. Significant doubts still exist in all countries despite variations in ODS pollution and management between established and emerging nations (SOLGCS, 2005)

Air pollution and acid depositions: Risks to ecosystems and human health

What are the effects of SO2 emissions on environments and human health that we should truly anticipate and prepare for in the future. Ecological studies conducted in the areas and nations that have already encountered this form of contamination, namely Europe and North America, have already produced this knowledge. The issue, known as acid deposition or more commonly as acid rain, includes the dry or moist accumulation of additional oxides in addition to sulphur oxides (SOx), most notably NOx. Although the occurrence has not yet ended, acid depositions are currently decreasing in Europe and North America. Additionally, based on local releases of SOx and NOx into the atmosphere as well as regional and local temperature, acid depositions may increase in other parts of the planet.

First and foremost, decision-makers recognised the issue of acid deposition when it was demonstrated that it was endangering ecological output and health, and indirectly, human health. Importantly, seafood and woodlands were where the harmful impacts of acid depositions were first discovered. The impacted environments were then the subject of additional data collection. For instance, geographically occurring acid depositions and weaker eggshells are correlated with avian population decreases. This indicates that the environment's acid-induced loss of calcium reduces avian diet, health, and reproductive success; however, the underlying processes are not always simple or obvious. The acidity of soils and surface waterways is controlled by the accumulation of atmospheric acid depositions on naturally occurring soil acidification processes. This harms habitats and has other detrimental effects.

CID depositions affect biological processes, which are essential to ecological health. First, they may reduce photosynthesis and consequently basic output and users (either alone or in conjunction with other variables). For instance, without limestone remedies, acid rain and the resulting stream acidity could significantly reduce or even wipe out entire populations of Atlantic salmon in Nova Scotia (Watt, 1986). The complicated soil biota is impacted by acid depositions, which also affects organic breakdown and nitrogen cycling. For instance, they have an impact on the communities of species that degrade, such as enchytraeid worms (Oligochaeta) and ecological interactions between soil arthropods (Abrahamsen, 1983). (Haagvar, 1984). Acid depositions also have an impact on soil microorganism activity, primarily through modifications to the nitrogen source (Killham et al., 1983). Comparable to how entire lichen communities may be destroyed to the point of extermination, reduced pH's impact on nitrogen fixation by their algae partner is most likely to blame.

While SOx emissions are rising in Asia and globally, acid depositions are currently trending downward in Europe and North America (Galloway, 1995; Barbier, 2005). Therefore, it is important to understand whether different natural mechanisms could help mitigate corrosive buildup. In some areas, like India, alkaline soil particles and fly ash may be able to stop the spread of acid rain. There are also known biological balancing systems. In base-poor forest environments, inadequate calcium inputs (such as those from air precipitation and mineral weathering of silicate minerals) can be made up for by the weathering of apatite (calcium phosphate) thanks to the activity of fungus living in association with the trees (forming ectomycorrhizae on tree roots). Directly absorbing the emitted electrons, the mushrooms then supply them to the plants. Through soil-based refuse breakdown, calcium ions are further recirculated into habitats. But not all tree types have these mycorrhizae, and the process is reliant on particular regional circumstances.

Acid rainfall have a long-term impact on environments. Large amounts of Ca and Mg may be lost from soil compounds and carried by draining waters as a result of acid rainfall and declines in the atmospheric deposition of base cations, delaying the recuperation of soil and water chemistry after decreases in acid deposition. Such lasting effects have the potential to cause sporadic acidity of waterways in areas where acid precipitation has previously occurred. Acidification of lakes and streams can be reversed scientifically. Although it is only partially feasible when corrosive intake never fully ceases, biological healing is also conceivable. Reestablishing normal pre-disturbance societies is a surprisingly upbeat viewpoint. Environmental "chronic disruption" has been used to describe this. Even though "acute disruptions" are frequently discussed more, both are harmful.

Crops may be affected by acid depositions in a number of ways, including substantial production loss in many species (Lee et al., 1981). However, excessive biomass removal in some terrestrial ecosystems (such as agricultural landscapes) may deplete nutrients and the ANC of soils, so that acidification may occur even without any acid deposition. Organic acids in soils moderate pH changes following reduction or cessation of acid deposition (Wright, 1989). When acid buildup occurs, it only makes things worse and prevents habitats that had been overexploited from recovering. In addition to SOx, NOx depositions may cause significant disruptions in natural environments. Because the nitrogen cycle is crucial for ecosystems, even slight rises in nitrogen pollution can cause detectable changes in ecological characteristics. According to some estimates, anthropogenic alteration of the nitrogen cycle has increased the global concentration of N2O (a GHG), increased the concentration of NOx, which contributes to the formation of ozone in the thermosphere (in smog), contributed significantly to the loss of nutrients that are essential for long-term soil fertility (e.g., calcium and potassium), and increased the transient variability of the nitrogen cycle.

The movement of trace elements and heavy metals in soils and waterways may also rise as a result of acidifying soils through the dry and moist accumulation of particulate oxides. 6Aluminum poisoning in trees may also rise as a result of subsequent cation nutrient loss, which adds to the decline of forests. NOx depositions, in addition to SOx, may cause significant disruptions in natural environments. Given the importance of the nitrogen cycle to ecosystems, even modest rises in nitrogen precipitation can produce detectable shifts in ecological characteristics. According to some estimates, anthropogenic modification of the nitrogen cycle has roughly doubled the nitrogen input rate into the terrestrial nitrogen cycle, increased the global concentration of N2O (a GHG), increased the concentration of NOx, which leads to the creation of ozone in the troposphere (in smog), contributed significantly to the loss of nutrients necessary for long-term soil fertility (such as calcium and potassium), and increased the transientThe movement of heavy metals and trace elements in soils and waterways may also rise as a result of acidity of soils caused by dry and moist accumulation of particulate oxides. The subsequent loss of cation nutrients may also raise the toxicity of aluminium in plants, which adds to the decline of forests.

Ozone is a serious issue for public health in towns and a significant source of pollution (associated with smog). It harms the airways, aggravates ocular irritation, and increases the risk of breathing illnesses in humans. Children and people with chronic illnesses are particularly susceptible. Ozone can seriously harm both earthly ecosystems, such as woodlands and agricultural lands, as well as marine environments, where algae thrive. It also slows down plant development, respiration/photosynthesis, and water use efficiency.

These are important problems needing social answers as well as technological elements for debate in specialised groups. Every nation needs to be conscious of how vulnerable its people are to the complicated impacts of environmental deterioration. The South Pacific Applied Geoscience Council (SOPAC) and the UNEP led group endorsed the environmental vulnerability index (EVI) suggested by Kaly et al. (2004), which does not expressly account for social factors. Instead, it makes use of 50 various environmental factors to rank each nation's environment (including ecological products and services) according to how susceptible it is to both natural and human dangers, using a measure of robust, at risk, vulnerable, highly vulnerable, and extremely vulnerable. Climate change, vulnerability to natural catastrophes, human health, crops and fishing, water, erosion, and wildlife are just a few of the broad problems that the environmental variables address. The findings show that, out of the 235 nations considered, 14 seem to be robust, 43 are at risk, 81 are susceptible, 62 are highly vulnerable, and 35 are exceedingly vulnerable to potential disruptions. The situation is exceedingly poor, especially among the 47 small island developing nations (SIDS), the majority of which are in the South Eastern Asia-Pacific region: none are robust, while three are at danger, 17 are highly susceptible, and 17 are extremely vulnerable.

The United Nations Development Programme's Bureau for Crisis Prevention and Recovery (BCPR) has suggested the disaster risk index (DRI) as an alternative metric (BCPR, 2004). The risks of human life loss in circumstances of medium- and large-scale catastrophes falling into any of the following three categories: earthquakes, hurricanes, and floods, are the only risks taken into account by this measure. Disaster risk is proxied by mortality, and the RDI was built using past statistics from 1980 to 2000. It is a mixed representation of the bodily exposure to severe events and susceptibility, not the danger of risky events per se. Because their capability for managing and adapting changes in response to severe events, vulnerability explains why nations with the same degree of exposure have varying risks of mortality. Economic (lack of savings and inadequate assets), social (deficient social structure and lack of social support systems), technological (unsafe buildings and dwellings), and natural (exposure to disasters) indicators of susceptibility

Environmentally conscious development

Adopting cleaner, environmentally conscious technology is necessary to combat air pollution. With the discussions and initiatives now underway to achieve sustainable development, ecological modernization is a significant topic. Modernizing the environment, however, does not guarantee sustainable growth. Instead, it is a prerequisite for sustainable growth, but not a sufficient one. In addition to ecological modernization, care must be taken with any programme and activity of capital management to prevent harming the natural capital in the name of protecting the environment. Because of this, the International Union for the Protection of Nature (IUCN) published a resolution in 2004 that urges the Precautionary Principle to be used as the basis for all environmental management and decision-making.

This idea is equivalent to the "insurance hypothesis" in ecology, which claims that biodiversity is beneficial for ecosystems because it confers overall stability in the face of disturbances or stressful conditions, as in the case of ecosystem structure. This idea has actually sparked a lively ecological "debate about diversity and stability," and an impressive volume of academic and practical data now supports the "insurance" viewpoint.

Because ecosystem resources will be preserved for future generations, the precautionary principle's application to the conservation of natural capital may satisfy both "technological sceptics" (who do not see much scope for technological development for the sustainable use of natural resources) and "technological optimists" (who see technological development as eliminating all barriers to growth and sustainable development). Accordingly, the definition of industrial hygiene evolved to include "anticipation, recognition, evaluation, and control of chemical and physical stressors whose presence or action may lead to undesirable outcomes such as injury or death".

Technology and science may even be ready to provide amazing answers for reducing global hazards. For instance, various methods for capturing and storing atmospheric carbon could be developed in order to take advantage of climate changes (IPCC, 2005). Technology by itself, though, cannot solve many problems. International (and not just national) agreements on environmental pollution are required for environmental regulations to be applicable. The Kyoto Protocol is a good example of a crucial advancement, as will be discussed later.

It is becoming increasingly clear that for technology to be environmentally friendly, it must give up its wholly artificial nature and become more hybrid—that is, both man-made and ecological. If biotechnology is used responsibly, it can fulfil this promise (Moser, 1994). It can help make the switch from an industrial chemistry that doesn't care about the environment to one that does (Cano-Ruiz and McRae, 1998; Gavrilescu and Chisti, 2004). The sixteenth chapter of Agenda 21 (UN Agenda 21, 2005), the UNEP's main agenda, is devoted entirely to biotechnology. Depending on their tolerance for different concentrations of different pollutants or mixtures of pollutants, different plant and animal species react differently to different levels of environmental pollution. When pollutants are present, biological performance may be only marginally and within physiologically tolerable limits, or it may experience fatal injuries and perturbations.

These are frequently protective mechanisms, such as the physiological changes in plants where pollutants change the root-to-shoot ratio and hasten leaf maturation. Any effective management requires an understanding of all these pathways through ecotoxicological and multiple-stress studies (Winner, 1994). Food webs are formed by the connections between below-ground systems, such as soil communities and chemistry, and above-ground systems, such as vegetation cover and associated herbivore and bacterial communities (Scheu, 2001). Animals act as resultants of various effects on ecosystem health, regulation and productivity, chemical cycling, and genetics (Newman and Schreiber, 1984). (Newman and Schreiber, 1984). Similar to this, lichens and mosses are frequently used in biomonitoring air pollution with trace elements due to their biological sensitivity.

Therefore, known species and populations may be used in empirical calculations of critical loads of airborne pollutants and as indicators of long-term trends in ecosystem responses to air emissions (Bobbink and Roelofs, 1995). Many ecological indicators are already available, that is, measurable characteristics of the structure, composition, or function of ecological systems. Chemical, physical, and other biological phenomena are detected by ecological indicators, which are primarily biological in nature. They capture innate, extremely complex dynamics and are helpful for assessing the state of ecosystem health.

Ecosystems under extreme stress, such as those in metropolitan and periurban settings, are less able to filter and absorb other contaminants. The main services that these ecosystems offer is air filtration (air pollutant retention), microclimate regulation, noise reduction, rainwater drainage, sewage treatment, and recreational and cultural values. These ecosystems are related to street trees, lawns/parks, urban forests, cultivated land, wetlands, lakes/seas, and streams. Making informed choices about land use by local and national authorities is crucial for reducing the negative impacts of air pollution on public health.

Biological and biotechnological methods, such as bioassays, are leaders in supplying managers with knowledge about the complex effects of pollutant substances on ecosystems and humans. Bioassays, such as ecotoxicological tests and biosensor systems, are bioresponse-linked methods of pollution analysis because pollutants present biotoxicity issues. Various biological-toxicological effects of known pollutants are being investigated and evaluated using ecotoxicological tests in both natural and laboratory matrices. For lab or on-site pollution screening, field biosensor instruments can be created. For the detection and measurement of pollutants in air, water, and soil, biosensor systems (also known as biosensors) use known biological-toxicity effects.

Such data, along with those from the biomedical literature, may further be taken over by ecologists and ecological economists and used in performing economical estimates of risks. Such economic analyses are needed to establish appropriate and authoritative degrees of regulations of pollutant emissions. Thus, the ecological, social, and economic efficiencies of policies are being addressed in an integrated manner. For example, based on ecotoxicological and biomedical research and on subsequent education of the population on the concrete risks of pollution, pesticide risk valuations and willingness-to-pay estimates can be used in policies of pesticide risk reduction.

This is essential because there is extensive evidence that poverty strongly prevents nations from abating many types of pollution (Hilton, 2006). This further leads to entire populations being caught in a vicious circle of overexploitation of natural resources and underdevelopment, with malign effects on the health, human development, and general welfare of individuals and of the nation (Barbier, 2005). For example, biosensors are a very promising new technology and tool for addressing issues of monitoring natural resources, but technology is today restricted to uses in developed countries, with very few exceptions. Still, such scientific progress in riches countries holds great hope for the future of poorer countries too.

Biosensors have the scientific ability to find contaminants in the environment that could be hazardous or have already been shown to be so, including those that are genetic, cancerous, hepatotoxic, nephrotoxic, immunotoxic, neurological, and metabolic (Richardson, 2003). Their use of biological components such as molecules (such as antibodies, DNA, and receptors), cellular organelles (such as chloroplasts), whole cells (such as cellular algae), or even tissues (such as plant tissues) open up a wide range of opportunities to combine analytical performance with specialised or straightforward or more complex biological responses. The development of highly integrated microdevices, such as molecules- or whole-cell-based lab-on-a-chip systems for ambient on-site analysis, dietary analysis, or medical point-of-care diagnosis, is made possible by advances in downsizing (Ciumasu et al., 2005; El-Ali et al., 2006). Interesting biosensors, as well as other physicochemical sensors taking advantage of advancements in micro- and nanotechnology, are being developed for the detection of airborne substances (for example, explosives) or pathogens (for example, with respiratory infections). These include the so-called nose biosensors or, more generally, electronic noses.

The majority of the costly science infrastructure, laboratory assets, and operating expenses that are unaffordable for the state sector could be replaced by highly integrated, tiny tools. Such tools will allow for trustworthy environmental and medical inquiries to provide benchmark data for risk evaluations and environmental and public health control in both emerging and established nations. Ecotoxicity research on heavy metals (e.g., Cu, Zn, Lead, Cd, Cr, and Ni) from atmospheric precipitation or other sources, for example, should consider their general flows in ecosystems, which are related to pollution burdens, soil type and acidity, flora, and land uses (Bergkvist et al., 1989). Endocrine-disrupting chemicals are another example of harmful contaminants. These are chemicals that are harmful.

dispersed into the ecosystem, interacting with vegetation and creatures (including humans, obviously). Because of their chemical similarity, they have the same metabolic effects as hormones and thus disrupt the regular working of animals and communities. Many contaminants, for example, imitate estrogenic action and thus cause "feminization" in the afflicted community. This has implications for community health and behaviour. Bioassays can be used to identify endocrine disruptors (e.g., molecular identification) as well as evaluate biological harm in people and environments. Ecotoxicity studies, along with environmental biotechnologies, provide a foundation for environmental cleaning and ecosystem regeneration by utilising natural processes that biological systems use to self-recover. Thus, phytoremediation of waters and soils makes use of certain plant species' ability to metabolically break down and assimilate chemical contaminants, either alone or (usually) in collaboration with several plant species as part of local ecosystems composed of plant and microbial (but also animal) communities. its great popular appeal (Cherian and Oliveira, 2005). Artificial marshes, for example, can be built to decontaminate water. Plants can be used to decontaminate dirt in a variety of ways, including on-site cleanup Given our discussion of aerial SO2 accumulation, it is pertinent to note that plant metabolization of sulphur can be used for plant cleaning in sulfur-enriched soils). Plants can also be used in phytoremediation techniques to remove flammable and semivolatile contaminants from the air

As the direct effects of pollution on ecosystems and human health become more obvious to the general public and easier to understand, bioresponse-linked and bioremediation technologies are natural supporters of public and professional discussions on pollution problems These two science fields should serve as bases for, and foster, EE and education for sustainable development initiatives for people of all ages.

Environmentally conscious development

In general, the ecological effects of environmental changes are examined using techniques from the interconnected categories of projection, trials, phenomenological models, game-theory population models, expert opinion, and outcome-driven modelling and scenarios. However, several significant issues confront natural resource managers: flexible management is preferable, but it is rarely used in practise for economic and political reasons. Much knowledge is frequently unavailable, and much conservation strategy is not evidence-based. This is frequently due to the high level of intricacy and unpredictability that many natural and human-driven processes exhibit (Sutherland, 2006). However, administrators must focus their efforts on preserving and growing ecological services, which includes all types of dangers presented by greenhouse gas pollution and climate change. Ecosystems, for example, can alleviate the impacts of catastrophes caused by climate change, such as pollution and flooding. Ecosystems (particularly trees) must be considered as water infrastructure and evaluated appropriately, using cost-benefit analysis, from an economic and financial standpoint.

Extrapolation, trials, phenomenological models, game-theory population models, expert opinion, and outcome-driven modelling and simulations are all used to explore the biological effects of environmental changes. However, several significant issues confront natural resource managers: flexible management is ideal, but is rarely used in practise for economic and political reasons. Much knowledge is often unavailable, and much conservation strategy is not evidence-based. This is frequently due to the high degree of intricacy and unpredictability associated with many both human and natural processes (Sutherland, 2006). However, administrators must focus their efforts on preserving and growing ecological services, which include all types of dangers presented by greenhouse gas pollution and climate change. Ecosystems, for example, can help to alleviate the impacts of catastrophes caused by climate change, such as pollution and flooding. Ecosystems (particularly trees) must be considered as water infrastructure and evaluated appropriately, using cost-benefit analysis.

The participation of insurance firms in implementing environmental-financial solutions may already yield remarkable outcomes. The territory of Panama is one such case. Because the Panama Canal's basin is deforested, the canal requires more upkeep funding than if the watershed was wooded. A wooded basin would discharge less water, but it would control this flow in time, which makes sense for the canal's locks to operate properly. Furthermore, a deforested basin enables more particles and fertilisers (including those from airborne precipitation) to enter the waterway, clogging it either directly or indirectly through the plentiful development of waterweeds. This necessitates frequent and costly cleaning. Trees collect silt and fertilisers. As a result, any investment in reforesting the basin was essentially an investment in infrastructure. Even if the state government cannot afford it, money can be obtained from the market. Insurance companies would ask their customers (who are presently insured for massive losses if the waterway were to shut) to accept pledges that would fund replanting. In addition to fiscal advantages, such a company offers ecological functions and societal benefits to the local community.

The centre of the answer in the preceding instances was market pricing of ecosystem products and services. The so-called carbon market is an illustration of broader worry. This follows the entry into effect of the Kyoto Protocol, which sets individual goal decreases in Carbon emissions in industrialised nations, on February 16, 2005. The cutbacks were mostly bargained based on each country's pollution past (UNFCCC, 2005). To prevent unsustainable costs from carbon-cutting goals, European nations introduced a pioneering pan-European carbon-trading scheme in 2005, allowing movement and effectiveness in meeting the approved objectives.

Direct help to breaking through what could have been a stalemate. Many opponents of the Kyoto Protocol, for example, believed that placing higher emission-reduction obligations on developed countries based on their past emissions records would result in industry delocalization from developed to emerging countries. The general argument is that strict environmental regulations may damage the viability of businesses in specific areas or nations, which would be outpaced by global rivals who are not subject to the same national or regional regulations. Several developed countries frequently cited economic growth as the primary worry and cause for not ratifying the Kyoto Protocol on reducing GHG emissions, despite the fact that the goal emission reductions are very modest (UNFCCC, 2005). Actually, the scientific community extensively attacked this tiny goal as being too feeble in its duty assigned to industrialised nations. Different possibilities even project that the agreed-upon goal decrease of only 5.3% of 1990-level GHG emissions by 2008-2012 will have minimal long-term effects on the environment (Wigley, 1998). The scholarly community pushed for a much more aggressive decrease.

Companies used to simply resist any effort to reduce carbon pollution; now, however, they are more divided; some have started to measure the market possibilities of engaging in greener technologies, including renewable energy production. Advances in ecologically friendly technology increase as the price difference between so-called green technology and conventional ones narrows and there are more chances to profit from new goods. This market trend is aided by improvements in green technology, particularly solar and wind electricity, as well as rising energy costs. Oil prices have more than quadrupled since 2001 as a result of rising oil consumption, particularly from developing countries such as China and India, and a lack of extra capacity in the oil sector. Novel and "cleaner" goods may be selected by consumers less for their "greenness" and more for the utilitarian benefits of being excellent and cheap (The Economist, 2005a,b). Recycled printer ink refills are an excellent illustration of such goods. Although these pioneering goods do not yet match the very finest, they are adequate and also less expensive. That is a good starting point. Markets are undoubtedly volatile, and poorly constructed carbon market systems may be ineffectual in assisting the environment. This is what happened recently with the carbon permits issued by the European Union Emissions Trading Scheme (ETS), which benefited power companies while doing nothing to reduce emissions because the ETS was only designed for three years, whereas companies require at least five years to plan the necessary investments (The Economist, 2006a). Another flaw in the ETS system was the recent leak of emission data through the European Commission website, which caused undue volatility on the carbon market. Yet, the system is theoretically functional, since it is comparable to the mechanism that regulates sulphur dioxide emissions in the United States (Schiermeier, 2006).

In nations where a mandated carbon-trading system does not yet exist, a similar market weakness exists with the concept of carbon "offsetting," which means that a firm may pay other companies to release less CO_2 on its behalf on a voluntary basis. Since this system is in its infancy, there are no rules, and it is being redirected to other uses, such as image polishing for polluting corporations and overzealous politicians.

The following example is based on such market and ecological economics perspectives. The almost pure CO_2 that is often dumped straight into the sky as waste by oil refineries may really be a useful product for agriculture. The so-called organic carbon dioxide for absorption by plants (OCAP) initiative, with a seemingly hazardous but promising investment, guarantees that this GHG is really carried via pipes and discharged into the greenhouses of surrounding agricultural producers (Stafford, 2006). The corporation has ignored its environmental issues while increasing its profits. Because of the greater CO_2 concentrations in the greenhouses, the greenhouse owners secured strong biomass production rates (which sequesters CO_2) and lowered heating expenses. Finally, waste CO2 contributes less to global climate change since most of it is "caught" as money. This is a notable illustration of how wise use of free-market principles may convert a problem into a benefit. While the director of the petrol supply firm refused to reveal the money generated by this initiative, his remarks are telling: "If there had been no financial rationale for OCAP, we would not have done it."

In reality, the notion that ecosystems and markets are inherently incompatible is one of the most significant threats to sustainability. They most likely aren't because they adhere to the same basic rules of energy allocation and consumption. Alternatively, if they are, we must devise the appropriate method to make them compatible. This is to suggest that market-driven GHG reductions are more than just fluid. Although the essence of the Carbon dioxide emission problem is its direct link to the global economy's current unsustainable reliance on oil, the answer is innovation. Churchill, the Prime Minister of the United Kingdom, stated in the mid-1950s that "safety and confidence in oil rest in diversity, and variety alone." Now, energy security (and the avoidance of horrific occurrences like oil shocks) is dependent on diversity. As the well-known monthly The Economist phrased it, "today diversity in energy sources, rather than just oil supplies, must be sought."

A culture of true sustainable development must be fostered in public opinion via the development of "ecological literacy", which has yet to be realised across countries and communities. This new literacy must provide the groundwork for controlling knowledge-action boundaries by developing efficient knowledge systems capable of mobilising technology and science for sustainable development.

From the standpoint of a scientist, ecological literacy and, as a result, more public participation in environmental concerns would correspond to what has been referred to as "a new social contract" for science and scientists (Lubchenco, 1998): the contract for sustainable development. To attain these two aims, effective EE and education for sustainable development programmes must be established and implemented, with a focus on merging scientific and public interests and welfare, as well as transforming political identities, connections, and institutions. To give an example, point 6.13 of Agenda 21, concerning national health care plans is a good starting point for educating the public (of all ages) on the continuity between environmental health and human, personal insurance. This point actually recalls many issues that we have chosen to discuss earlier in this chapter.

To give another, more concrete example, human resources for sustainable development are being developed through a pilot EU project on EE that was recently launched under the auspices of the European Commission as part of the Leonardo da Vinci programme and is concerned with the "development of a European curriculum for methodological training in the field of EE." Wide ecological changes are occurring, notably in the emerging nations of Central-Eastern Europe (the erstwhile communist block.

This project's rationale was to bring together representatives of target groups (from universities, preuniversities, climate NGO sectors, environmental agencies, botanical gardens, natural science museums, and parks and natural reserves from Romania and Bulgaria) and EE specialists from various European nations, both developing (Romania and Bulgaria) and developed (France, Germany, and Spain). The initiative is based on the spirit of Agenda 21, and it incorporates academic knowledge from ecologists, biologists, sociologists, psychopedagogists, and economists, as well as practitioners of formal and nonformal EE from participating nations. Education for sustainable development is our greatest bet in what Edward O. Wilson refers to as the "Century of the Environment" and the "bottleneck" of the near future. We agree with him that integrating science and technology with foresight and moral bravery is the best approach to ensure humanity's long-term future. Above all, this education should attempt to establish a reflex for weighing short-term economic advantages against long-term repercussions on our ecological, social, and economic systems. Human dominance of the Planet characterises our age. This, however, should be replaced with accountability and a return to a more long-term connection, one that is at the heart of every natural ecosystem: dynamic equilibrium.

CHAPTER - 20

REGIONAL AND GLOBAL ENVIRONMENTAL ISSUES OF AIR POLLUTION

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There is mounting evidence that human activities in a more globalised, industrialised, and networked globe are having an impact on air quality and climate change at all sizes, from urban to regional to continental to global. Rapid In July 2009, the global population was at 6.8 billion, 313 million higher than in 2005, with an annual increase of 78 million people (UN, 2009). 5.6 billion (or 82% of the global population) will live in less developed areas. The majority of growth happens in urban regions; in 2008, urban areas housed half of the world's population for the first time in history (UN, 2008). To create electrical energy, push transportation, power industrial operations, cook food, and provide heat and ventilation for households, business enterprises, and public buildings, the world's increasing metropolitan regions require a considerable portion of the Earth's present fossil fuel budget. Emission levels from these fossil fuel combustion sources, as well as the activities they power, release significant amounts of gases and fine particulate matter (PM) into the atmosphere, causing major health and environmental implications.

Significant reductions in harmful emissions to the environment are attainable via a mix of technological advancement and legislative changes. Indeed, air pollution has reduced in certain locations throughout the globe when efficient emission control techniques and increased energy efficiency have been applied. Yet, many locations continue to suffer from severe air pollution, particularly in Asia, where the most polluted cities are currently concentrated. Every year, energy consumption and transportation demand rise, accounting for a significant portion of both anthropogenic greenhouse gas (GHG) output and unfavourable health consequences from air pollution. This is due to the massive industrial development in many emerging nation cities that produce items for the global economy, as well as the comparatively rapid rise in private vehicles as their residents become more prosperous. Solving the issue of rapidly increasing cities with severe air pollution, even as their living standards improve, has emerged as one of the most pressing environmental concerns.

Sources and Transport of Atmospheric Pollutants

Air pollution may be both natural and man-made. Gases such as sulphur dioxide (SO2), hydrogen sulphide (H2S), and carbon monoxide (CO) are regularly released into the atmosphere as a consequence of natural occurrences such as volcanic activity, plant breakdown, and forest fires. Fine particles are dispersed throughout the atmosphere by wind, forest fires, volcanic eruptions, and other natural disturbances. In contrast, human-caused air pollution has become a severe and chronic concern in many urban/industrialized places across the world. Substances like CFCs are chemically exceedingly inert and essentially insoluble in water, therefore they are not eliminated by the troposphere's cleaning systems. These chemicals can survive in the atmosphere long enough to drift into the stratosphere, where they are ultimately destroyed by high-energy solar radiation to produce radicals capable of destroying stratospheric ozone through a catalytic process (Molina and Rowland, 1974; Molina and Molina, 2005). Compounds like NH3 and hydrogen chloride, on the other hand, are swiftly eliminated by rain, with a time scale of weeks on average. Hydrocarbons and NOx are also eliminated swiftly on a global scale: hydrocarbons are not soluble in water, but are oxidised by different species such as the hydroxyl radical (OH), which changes them to soluble molecules that are subsequently removed by rain. NOx is mostly removed by rain after being converted to nitric acid, which leads to acid deposition. Hydrocarbons and NOx are responsible for the worsening of air quality on a local and regional scale by generating ozone and secondary PM. The most photochemically and oxidatively active hydrocarbons breakdown in minutes, whilst the less reactive ones might survive for hours, leading to the generation of ozone and particulates downwind from the sources from which they are produced.

Impacts of Air Pollution

Air pollution used to be considered as a local concern rather than a long-term global change issue. As mentioned in the previous chapters in this book, air pollution can adversely affect human health by direct inhalation and by other exposures such as contamination of drinking water and food and skin transfer. However, the atmosphere is a shared resource that respects no boundaries; air pollutants do not stop. when they reach city or national borders. When air pollutants are discharged into the atmosphere, they may be transported by winds, mix with those other pollutants, undergo chemical changes, and finally be deposited on different surfaces. As a result, their effects may be felt far from their origins. In the case of acid deposition and stratospheric ozone depletion, the global and regional dispersion of pollutants created locally has been well demonstrated. Long-range transport of tropospheric ozone has recently been seen to be growing over the Northern Hemisphere. POPs from industrial economies are being carried to the Arctic across large distances. Arctic Haze is caused by air pollution and wildfire emissions from the northern mid-latitudes.

Emissions from developed-world urban and industrial centres, and increasingly from developing-world big cities, are altering the chemical composition of the downstream troposphere in a variety of basic ways. Large cities' polluted atmospheres often include significant quantities of PM, O_3, SO_2, CO, NOx, and volatile organic compounds (VOCs). Tss particulates (TSP), PM10, and PM2.5 (particles having aerodynamic dimensions smaller than 40, 10, and 2.5 m, respectively) are often reported as mass concentrations of PM. Sulfate (SO4 =), nitrate (NO3 -), ammonium (NH4 +), organic carbon (OC), elemental carbon (EC), and soil dust are the key chemical components of PM.

CO, NOx, and VOC emissions contribute to the production of photochemical smog and its related oxidants, lowering air quality and endangering both human and ecological health. On a bigger scale, these same pollutants contribute considerably to global warming by driving the creation of ozone (a potent GHG) in the free troposphere. Urban and industrial regions are also significant producers of GHGs such as CO_2, methane (CH_4), nitrous oxide (N_2O), and halocarbons. On regional to continental scales, NOx and SO_2 emissions are also converted to powerful acids by atmospheric photochemistry, causing acid deposition in sensitive ecosystems and material deterioration, including historic structures and monuments. Direct urban/industrial emissions of carbonaceous airborne particles are exacerbated by secondary aerosol precursor emissions such as NOx, VOCs, SO_2, and NH_3. The ensuing mixture of primary (directly emitted) and secondary (produced as a consequence of subsequent photochemical and chemical reactions) aerosols is now known to have an essential impact in Earth's climate. In the sections that follow, we will look at some of the regional and worldwide implications of air pollution.

Visibility Impairment and Regional Haze

Cities with poor air quality may be identified by their hazy environment and limited vision, which can be distinguished from natural fog and clouds. The relationship between air contaminants and visibility is a well-known phenomenon. The impact is mostly caused by the presence of tiny particles in the atmosphere, which are either directly released or generated via chemical transformations of gaseous contaminants. Moreover, loss of vision offered early warnings of the dramatic impacts of human activity on the atmosphere. For example, Los Angeles had its first significant smog outbreak in the relatively high frequency of foggy days contributes to reduced visibility in Beijing, China. Even when there is no fog or cloud cover, the sky above is generally gloomy. Bergin et al. (2001) performed a study of the physical and chemical features of aerosols in Beijing in June 1999 and determined that combustion-related particles were mostly responsible for vision degradation during that time period. But, in the spring, sand storms and dust frequently cause extremely poor vision (Yang et al., 2002). Dust and sand storms that start in the arid areas of northern China and Mongolia and blow through sections of China, the Korean peninsula, and Japan occur in the spring months when cold air masses from Siberia whip deserts and soils eastward after the dry continental winter. These storms' severity and frequency have recently increased (Molina et al., 2004). Apart from the dust and sand storms discussed above, clouds of small aerosol particles from human emissions hover over a number of places. These seasonal layers of haze restrict the quantity of sunlight that reaches the Earth's surface, potentially affecting air quality, temperature, and the hydrological cycle (Ramanathan et al., 2001).

Acid and Fixed Nitrogen Deposition

The first commonly documented regional-scale environmental effect caused by urban and industrial pollution is acid deposition (acid rain). The air oxidation of NOx and SO2 (emitted during combustion) into nitric and sulfuric acid drives the process. When these acids, and the sulphate and nitrate aerosols they produce, are deposited downwind on poorly balanced surface waters or soils, they have a negative impact on sensitive lakes, streams, forests, and farmlands (NAPAP, 1990). Regional acidification air pollution concerns have been decreased in Europe and North America, but they are now an increasing policy priority in areas of Asia, where acidic deposition has grown.

A closely connected issue is the fertilising effects of airborne fixed nitrogen species (ammonium and nitrate aerosols and their gas-phase precursors) on buffered soils and fresh or marine surface waters that are not acidic. When combined with fixed nitrogen and phosphorus from fertiliser, animal waste, and human sewage, atmospheric nitrogen deposition can help overfertilize soils, lakes, streams, and estuaries, resulting in changes in primary productivity (excessive plant growth and decay) and, potentially, eutrophication (Galloway, 1996). This increased plant growth is generating a number of issues, including a shortage of oxygen in the water, which is required for fish and shellfish to thrive, as well as significant declines in water quality. It has recently been shown that large amounts of fixed nitrogen deposition may have a considerable impact on ecosystem diversity, even when deposition receptor regions are not severely acidified.

Photochemical Oxidant Damage

As urbanisation grows, it is becoming clear that photochemical oxidant generation is becoming a regional issue. Photochemical oxidants are the byproducts of NOx reactions with a broad range of VOCs. Ozone, peroxyacetyl nitrate (PAN), and hydrogen peroxide are the most well-known oxidants (H2O2). Photochemically formed oxidants and their precursors emitted from big cities regularly created high amounts of ozone and other oxidants all the way to nearby cities, exposing suburbs, woods, and agricultural regions. Regional-scale effects of tropospheric ozone on agricultural yields have been estimated to cost US$ 5.7-12 billion per year for 23 arable crops in 47 European nations. It has been claimed that tropospheric ozone damage may have a considerable influence on crop yields in key agricultural regions touched by emissions from large Chinese cities, as well as India and Pakistan. Gregg et al. (2004) finds stronger plant growth in New York City compared to a rural setting, attributing the impact to higher ozone levels in the rural location studied. Severe damage to trees around the Mexico City air basin has been recorded as a result of exposure to high levels of photochemical oxidants (mostly ozone).

Effects of PM on Photosynthetically Active Radiation

Aerosol particles are widely recognised for influencing the climate system via direct and indirect interactions with solar radiation Another impact of the aerosol direct influence on solar radiation has recently been studied, specifically the effect on vegetation carbon uptake owing to a decrease in total Photosynthetically Active Radiation (PAR) at the Earth's surface and an increase in the diffuse component of PAR (Cohan et al., 2002). This spectral area roughly corresponds to the spectrum of light visible to the visual system (400-700 nm) that photosynthetic organisms may employ in the photosynthesis process. Recent model assessments show that Asian megacity SO2 emissions have a significant influence on regional SO2 pollution. High levels of regional SO2 and other fine PM precursors can produce extremely high levels of fine PM with absorption and scattering properties that influence both the direct and diffuse components of PAR (Cohan et al., 2002); the resulting haze over eastern China has measurably reduced solar radiation reaching the surface since 1954. (Kaiser and Qian, 2002). It has been proposed that the reduction of PAR by both air PM and PM deposited on plant leaves may have a major influence on the solar radiation available for photosynthesis in key agricultural districts of Chinac [27].

Regional Climate Change

High amounts of air pollution released by urban/industrialized regions may have an impact on regional climate. Long-lived primary GHG emissions from big cities have a direct worldwide influence on infrared radiative forcing. Additionally, large regional air concentrations of the potent but short-lived tropospheric ozone will have a more marked regional impact. Over the period 1860-2004, Asia had a gradual and accelerated long-term warming trend. In recent years, Australia has experienced severe drought and had its warmest year on record, as well as its hottest April, in 2005. In Europe, the average temperature has risen by around 1.4°C since preindustrial times.

Effects of PM on Sunshine Duration and Temperature

By scattering and/or absorbing solar light, fine particles may have a direct influence on short-wavelength radiative forcing. Notwithstanding a global warming, surface temperature data in certain urbanised areas of China and India (Menon et al., 2002) demonstrate a noticeable cooling in recent decades. Studies of meteorological data from several monitoring stations in China's densely populated areas show substantial negative trends in both sunlight duration (1-3% per decade) and maximum daily temperatures (0.2-0.6 K per decade) (Qian and Giorgi, 2000; Kaiser and Qian, 2002). The observed cooling trends are consistent with the projected consequences of high levels of fine particles in soot, which heat the air, disrupt regional atmospheric circulation, and contribute to regional climate change.

Effects of PM on Precipitation and Clouds

Aerosol particles in the atmosphere are critical to the existence of clouds as we know them. High aerosol loadings may impact precipitation levels by increasing cloud lifetimes and suppressing rain and snow by nucleating more, but smaller, cloud droplets. Satellite data suggest that rainfall is significantly suppressed downwind of big cities (Rosenfeld, 2000). High PM loadings with a high proportion of absorbing soot particles are projected to diminish cloudiness by absorptive heating of air masses (Ackerman et al., 2000), while the actual effect on cloud cover may be influenced by the enhanced atmospheric circulation caused by this heating (Menon et al., 2002). Nowadays, establishing climatically relevant correlations between aerosol, clouds, and precipitation is quite challenging.

Long-Range Transport of Air Pollutants

Because of the wide-ranging consequences for human health and ecosystems, visibility degradation, cloud seeding, changes in radiative forcing, and tropospheric oxidation capacity, the export of air pollutants from urbanised regions to sensitive environments has become a major concern with the growth of multicity "megalopolis" regions in North America, Europe, East Asia, and South Asia. The Arctic, for example, is often regarded as a pristine environment, but its atmosphere has served as a receptor for air pollution from northern mid-latitude industrial regions, as evidenced in particular by thick aerosol layers (Arctic haze) and the accumulation of persistent pollutants such as mercury. The haze has an effect on the highly reflecting Arctic ice sheet, raising temperatures both in the atmosphere and on the Earth's surface. In 2008, ARCTAS (Arctic Research on the Composition of the Troposphere from Aircraft and Satellites) was initiated as a large field project to determine how air pollution contributes to climate change in the area.

Observations from the ground, aircraft, and satellites have provided a wealth of evidence that air pollution can be transported over long distances, such as from eastern Asia to the western United States, from North America to Europe, and from mid-latitudes to the Arctic. A rising corpus of observational data, including new information from extensive field campaigns and satellite-borne equipment, enhanced emission inventories, and global and regional chemical transport models, has recently increased our capacity to measure the volume of transport. Many investigations have demonstrated A transport.

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