ENVIS NEWSLETTER

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Indian Institute of Tropical Meteorology, Pune

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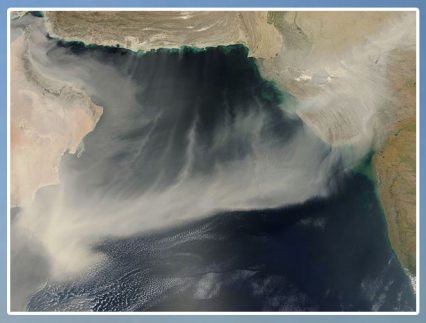
AIR POLLUTION CHEMISTRY – 1

CRITERIA POLLUTANT- PARTICULATE MATTER



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Editorial

Environment is the essential component of human life on which all living things depends for survival. There is a continuous interaction going on in each component of Earth system, change in one component affects the functioning of other either in positive or negative way and hence unsustainable use of natural resources during past few decades disturbs the functioning of Earth's ecosystem and alter the normal composition of Earth's atmosphere significantly. This result in the severe problems like acid rain, global warming, climate change, biodiversity loss, air pollution etc. and place the striking problems like food security, energy security, unpredictable weather in front of human race. To tackle these issues one need to know the present scenario of our atmosphere and how it changed over period of time; also the knowledge of major components which are responsible for this alteration is important. In view of these we are writing the series of ENVIS newsletters under the heading of "Air Pollution Chemistry" which will starts by giving you the basic information of our atmosphere, its normal composition, anthropogenic drivers of air pollution, climate change, and ends by conveying you there effects on our environment.

Present issue gives you detailed information regarding emission source and levels of Particulate Matter one of the criteria pollutant. We hope our attempt to convey complicated scientific information in simple langues will help to create awareness amongst the common public which is the first step towards safeguarding our environment.

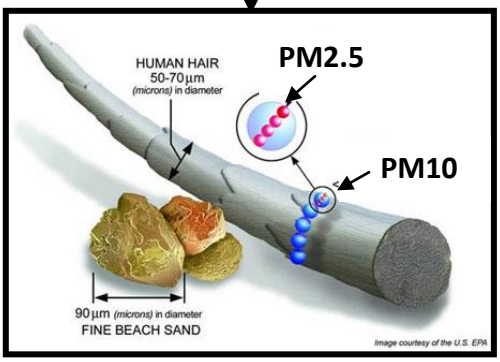
Criteria Pollutants

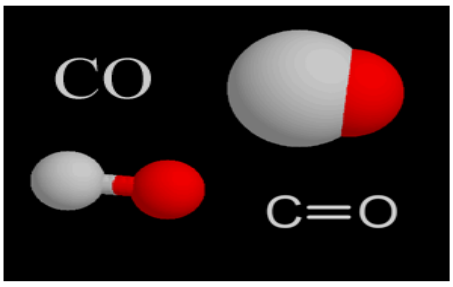
The five commonly found air pollutants in the atmosphere are particulate matter (PM), ground-level ozone (O_3), carbon monoxide (CO) and nitrous oxides (NO_X). Environment Protection Agency (EPA) identified these pollutants as "criteria" air pollutants because they can harm health and the environment.

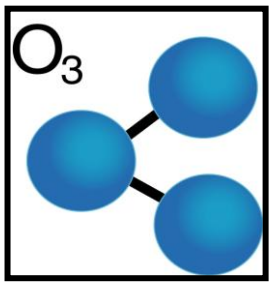
It is evident from the medical records that short term exposure to these pollutants show immediate symptoms like coughing, eye and respiratory tract irritation, difficulty in breathing, headache, dizziness, visual disorders and memory impairment. Besides this prolonged exposure to these pollutants adversely affect lung, heart and brain functioning causing diseases like asthma, lung cancer, chronic respiratory disease, acute respiratory symptoms, decreased lung function, soreness of the nasopharynx and lungs etc. Hence study of these pollutants become important to reduce the associated health risk.

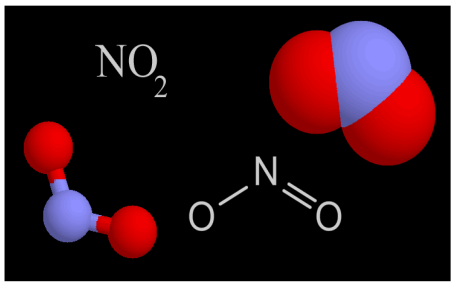
CRITERIA POLLUTANTS

Particulate Pollutants









Gaseous Pollutants

Particulate Matter (PM)

Particulate matter (PM) is the term used for a mixture of solid particles and liquid droplets or both suspended in the air and represent a complex mixture of organic and inorganic substances.

Numbers of terms are used to categorize particles depending on their size and phase (solid or liquid). The most general term used is aerosol; it is the suspension of solid or liquid particles in a gas. Solid particles are called as dust if they are caused by grinding or crushing operations, they are called as fumes if they are formed when vapors condense and they referred as smoke and soot if they primarily compose of carbon that result from incomplete combustion. Liquid particles may be called as mist or fog. These particles vary in size, composition and origin.

PM is often non spherical and have irregular shapes. Their actual geometric size is difficult to measure therefore their size is described by an equivalent aerodynamic diameter, which is determined by comparing them with perfect sphere having the same settling velocity. The size of the particles determines the time they spend in the atmosphere.

Depending upon the size and time for which they remain airborne, PM can be grouped in to three main categories.

i. Aitken nuclei or Aitken particles

All particles having aerodynamic diameter less than 0.1µm are called Aitken particles or Aitken nuclei.

ii. Suspended Particulate Matter (SPM)

The size of Suspended Particulate Matter ranges from 0.1µm to 10µm. The settling velocity of these particles is very low and therefore the particles remain suspended for long periods (from hours to weeks) in air.

Out of these SPM **the particles having an aerodynamic diameter less than 10 µm are known as Respirable Suspended Particulate Matter (RSPM) or PM10**. The lifetime of PM10 is from minutes to hours, and its travel distance varies from <1km to 10 km. **The particles having aerodynamic diameter less than 2.5 µm are called as fine particles or PM2.5.** Lifetime of fine particles is from days to weeks and travel distance ranges from 100s to >1000s km.

iii. Dust-fall Particles (Settleable Particulate Matter)

These are the particles larger than the 10µm and tend to settle out due to gravitational force.

The chemical composition of PM depends on their source. Depending on the origin PM can be made up of hundreds of different chemicals such as nitrate, sulfate, ammonium, chloride, magnesium, calcium, potassium, trace metals, mineral salts, crustal element and carbonaceous material. Carbonaceous material is a dominant component of fine particle, contributing 20–40%, even up to 80% to the total mass of fine particles in the urban and industrialized areas.

Carbonaceous fraction consists of both elemental carbon (EC) and organic carbon (OC). EC is also known as black carbon (BC). The chemical composition of PM determines its effect on health and environment.

Levels of PM

Anthropogenic emissions in Asia are larger than those in Europe and North America today and will continue to increase in the future (Akimoto, 2003).The MODIS instrument on NASA's Terra satellite has been tracking the particulate pollution for more than seven years. According to measurements taken with a satellite instrument, vast quantities of industrial aerosols and smoke from biomass burning in East Asia and Russia are traveling from one side of the globe to another. Data collected by a NASA satellite shows a dense blanket of polluted air over the Northwestern Pacific. This brown cloud is a toxic mix of ash, acids, and airborne particles from car and factory emissions, as well as from low-tech polluters like coal- burning stoves and from forest fires.

The World Health Organization (WHO) & United Nations Environment Programme (UNEP) are collaborating since 1974 on an urban ambient air monitoring projects. Their report shows that 80% of the world's megacities are exceeding the maximum permissible limit of PM. Study conducted by World Bank's Development Research Group on annual ambient concentrations of PM in world cities with populations exceeding 100,000, shows that most of the cities exceeding the World Health Organization guideline values of PM are from Asia. At present the China becomes the world's most populated country, with doubling its emissions of tiny particles because of its rapid industrial growth, massive human migrations to urban areas, and considerable expansion in automobile use over the last two decades.

India is one of the fastest growing economies in Asia. According to the report publish by TERI, the available data in India show that pollutant concentrations are typically within the national ambient air quality standards with the exception of particles.

The most polluted metropolitan cities of India are Mumbai, Kolkatta and Delhi.

Sources of PM

The PM can be emitted directly as primary PM, and it can form in the atmosphere through the reactions of precursors to form secondary PM. Primary PM can be emitted either naturally or from human (anthropogenic) activities, the predominant sources are construction sites, unpaved roads, fields, smokestacks or fires, while secondary PM, is formed in complicated reactions in the atmosphere of chemicals such as sulfur dioxides and nitrogen oxides that are emitted from power plants, industries and automobiles.

Natural Sources of PM

Sea salt

One of the most important individual types of solid fine particles in the atmosphere is ocean salt, which is mainly sodium chloride. Such particles are very important because they are very numerous, are widespread over both oceans and continents, and play an important role in cloud formation. The concentration of salt over the oceans may be as great as 100 particles per cm^3. Sea salt particles are complex mixtures of sodium chloride, inorganic substances and organic substances both dissolved and suspended in the sea water. Pure sodium chloride crystals are hygroscopic, forming droplets, when the relative humidity exceeds about 75%, in contrast when relative humidity drops below this figure, salt droplet evaporate completely to produce solid particles. Over the ocean sea salt concentration decreases with increasing altitude, while over the continent the concentration of particles increases with increasing altitude through the first few hundred feet above which the concentration is fairly constant.

Forest fires

Another important source of particles consists of grass, brush, and forest fires. Even a small fire introduces vast numbers of small particles in to the atmosphere. It has been estimated that an average grass fire, extending over one acre, produces about 2×10^{22} fine particles. These particles range in composition from inorganic ash through carbon to complex tars and resins. Particles emitted from forest fires eg. Smoke can travel great distances.

Dust storms & sand storms

Particles from the soil and rocks constitute an important portion of the particle loading of the atmosphere. This makes up the majority of particulate matter less than 10 micrometers in size across the globe.

Volcanoes

Volcanoes are the important source of fine particles in the atmosphere. The volume of fly ash thrown in to the atmosphere by a powerful volcanic eruption has been estimated to be as much as 100 billion cubic yards. Much less violent volcanic eruptions may be very important contributor to the particle content of the atmosphere as they emit huge quantity of fume.

Biological material

Biological materials are another important constituent of the atmosphere, especial because of their biological action. Particles of biological origin include viruses, bacteria, fungi spores, pollen grain etc.

Anthropogenic Sources of PM

Anthropogenic particulates are defined as particulates originating from human activities at a rate not normally observed in nature. Fossil fuel combustion and biomass burning are believed to be main anthropogenic sources of PM. Fossil fuel burning involves the burning of coal and petroleum products including gasoline, diesel, oil etc. which is predominantly practiced in the industrial and

transport sector. Biomass burning involves burning of wood, charcoal, crop residues etc. which predominantly practiced in the residential and commercial sector. In addition large amount of PM are released in to the atmosphere through agriculture residual burning, municipal solid waste open burning etc. Other anthropogenic sources of PM involve Fugitive emissions from coal production, oil refinery etc, dust emission from construction activities and emissions from paved and unpaved roads.

Vehicles

In general vehicles have been powered by internal combustion engines which operate on fossil fuel combustion (gasoline, diesel, LPG).Vehicles contribute to the particulate matter emission by three mechanisms; primary PM emission, secondary PM formation and fugitive emission. The particles which are directly emitted through vehicles are called as primary particles. They are emitted from vehicle exhaust and also get emitted via break and tire wear. The primary particle emission from vehicle exhaust is in the PM2.5 size range while most of the particles formed because of tire wear are very large. Secondary particles are produced in the atmosphere through the reactions of gaseous emissions, e.g. hydrocarbon reacts in the atmosphere to form less volatile species that condenses in to the particle phase, contributing the carbonaceous particle burden. NOx oxidizes to the nitric acid which reacts with ammonia to form ammonium nitrate. The amount of ammonium nitrate in the particle is the function of the temperature. SO_2 is oxidized to sulfuric acid, which exist primarily in the particle phase.

Re-suspended particulate emissions from paved and unpaved roads originate from the loose material present on the surface and spillage of material. When vehicle travels an unpaved road, the force of the wheel on the road surface causes the pulverization of surface material where the particles are lifted and dropped from the rolling wheels and the road surface is exposed to the strong air currents in turbulent shear with the surface. The amount of dust generated is a function of the amount of fine particles (silt) on or near the roadway. This is a major source of PM10 and the emissions of PM2.5 are very less from this source.

Industrial sources

India has become the tenth most industrialized country in the world. PM pollution and the resultant impacts in India could be broadly attributed to the emissions from both large scale and small scale industries. The industrial units in India are largely located in the states of Gujarat, Maharashtra, Uttar Pradesh, Bihar, West Bengal and Madhya Pradesh. Some industrial areas in Delhi, Punjab, Rajasthan and Andhra Pradesh are becoming critical.

The Ministry of Environment and Forests had identified 17 categories of polluting industries. Out of which thermal power stations, iron and steel plants (sponge iron plants and steel

re-rolling mills), cement plants, brick making units, fertilizer plants, oil refineries, pulp and paper, petrochemicals, sugar, distilleries and tanneries are some major industries which contribute to large PM emissions.

Biomass (Biofuels) combustion

Biomass materials are used since millennia for meeting the need of energy. Main sources of biomass energy are trees, crops and animal waste. With rapid increase in fossil fuel use, the share of biomass in total energy declined steadily through substitution by coal in the nineteenth century and later by refined oil and gas during the twentieth century. Despite its declining share in energy, biomass contributes over a third of primary energy in India. In India Biomass fuels including wood, crop waste and dung cakes are predominantly used in rural households for cooking and water heating, they are also used in traditional industries. Its use accounts for 47% of the total energy consumption. Among the biomass energy sources, wood fuel is most prominently used in India and it contributes 56 % of total biomass energy.

Two main problems associated with the traditional biomass are inefficient combustion technologies and environmental hazards from indoor pollution. In rural India biofuels are burnt in small, open-chamber, Chulhas. Incomplete combustion of Biomass results in the emissions of small particles (PM2.5) with a large carbonaceous fraction and inorganic water soluble ions. These pollutants cause considerable damage to health, especially of women and children who are exposed to indoor pollution for long duration.

Apart from above mentioned various sources **Agricultural field burning and forest fires, Municipal solid waste (MSW) burning and Construction activities** are major sources of PM. Post harvesting field burning is a common practice in India. In India Around 25% of the crop residue generated during each cultivation is burnt in the agricultural fields (Reddy et al., 2002). Large amount of particulate matter (PM10 &PM2.5) is released in to the atmosphere along with different gaseous pollutants. Burning of MSW in incinerator results in the emission of particulate matter through its exhaust air also open burning of MSW normally occurs under relatively low temperature which release a large emission of pollutants such as PM (PM10 & PM2.5) and particulate BC, OC.

Construction activities that contribute to particulate pollution are land clearing, operation of diesel engines, demolition and burning. All construction sites generate high levels of dust (typically from concrete, cement, wood, stone, silica) and this dust is carried away in the atmosphere for large distances over a long period of time. Construction dust is mainly of the size of 10 µm.

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