ENVIS NEWSLETTER

INDIAN INSTITUTE OF TROPICAL METEOROLOGY, PUNE

(A Project of the Ministry of Environment and Forests, Govt. of

Volume No: 7
Issue No: 2
April- June 2009

Contents

Editor's Desk:

Once again, we are happy to bring out this ENVIS Newsletter Vol. 7, No.2. In this issue we have tried to elucidate in brief, the effects of "Particulate Matter (PM)" another pollutant found in atmosphere (size of particles ranging between 1 µm to 2.5µm) which seems to be affecting the climate as well as health of individuals to a great extent.

The issue will provide some basic understanding of this existing pollutant, its consequences on current climate change scenario, and human health along with some simple strategies which can help us to handle the situation.

We thank to all of you who contributed valuable articles and suggestions for our Newsletters, it would be highly appreciated if you could keep up for our future improvement.

What is Particulate Matter?

"Particulate Matter (PM)" refers to the sum of all solid and liquid particles suspended in a medium such as air for some time. Thus, airborne particulate matter represents a complex mixture of organic and inorganic substances (of human or natural origin). The complex mixture may comprise of, for instance dust, pollen, soot, smoke, and liquid droplets. In brief, the particle sizes not only vary in size ranges such as coarse, fine and ultrafine but they also differ in composition as well as origin which may prove to be hazardous.

Based on the size of their aerodynamic diameter, which is supposed to be the key factor, particles can be classified as PM_{10} (coarse and fine particles), $PM_{2.5}$ (fine particles) or $PM_{0.1}$ (ultrafine particles). Mass and composition in urban environments tend to be divided into two principal groups: coarse particles and fine particles. The barrier between these two fractions of particles usually lies between 1 µm and 2.5 µm. However, the limit between coarse and fine particles is sometimes fixed by convention at 2.5 µm in aerodynamic diameter ($PM_{2.5}$) for measurement purposes.

The larger particles, called coarse fraction, are mechanically produced by break up of larger solid particles. They usually comprise of earth crust materials and fugitive dust from roads and industries.

The smaller particles, called the fine fraction, are largely formed from gases and contain the secondarily formed aerosols (gas-to-particle conversion), combustion particles and recondensed organic and metal vapours. The fine fraction also contains most of the acidity (hydrogen ion) and mutagenic activity of particulate matter, although in fog some coarse acid droplets are also present. Whereas most of the mass is usually in the fine mode (particles between 100 nm and 2.5 µm), large number of particles are found in very small sizes, less than 100 nm. As projected from the relationship of particle volume with mass, these ultrafine particles often contribute only a few percent to the mass, at the same time contributing to over 90% of the numbers.

PM Sources: *As stated earlier,* Particulate matter may be in the form of fly ash, soot, dust, fog, fumes etc. The major PM components include sulfate, nitrates, ammonia, sodium chloride, carbon, mineral dust and water. The particles are further classified as primary or secondary depending on their formation mechanism.

Primary particles are directly emitted into the atmosphere by anthropogenic processes such as combustion (eg: burning of fuel, combustion from car engines/ vehicles etc.) and natural processes (eg: windblown dust), whereas, secondary particles are indirectly formed in the atmosphere by transformation of emitted gases such as SO_2.

Purging of PM: Sedimentation and precipitation removes PM_{10} from the atmosphere within few hours of emission, however, $PM_{2.5}$ may remain there for days or even for a few weeks. Consequently, these particles can be transported over long distances.

In conclusion, the aerodynamic properties prove to be very helpful in classification of the particles because:
(a) These properties govern the transport and removal of particles from the air.
(b) They also govern their deposition within the respiratory system and
(c) They are associated with the chemical composition and sources of particles.
(d) In addition, the size of the particles also determines the time they spend in the atmosphere.

Particulate Matter:Health Effects

The affliction sited on human health by particulate air pollution is a global one, one caused with inequality. Most prominent here is the imbalance between the developed and developing countries where the burden of ill health is attributable to particulate matter (PM) in air which is a critical problem of growing concern. The developing countries, nowadays, are quite commonly experiencing the same particulate matter levels which were supposed to be the root cause of the devastating “London fog episodes” of 1950s which resulted in over 4000 cases of premature mortality and countless cases of morbidity related health endpoints. Thus, there is little doubt that particulate matter causes or contributes to premature mortality and morbidity related health endpoints in developing countries.

Copious evidences supporting the realism that most harmful effects of particulate matter are related to the size of the particles are now available. As particle size decreases, the particles are conceived to either increase in acidity or in their ability to penetrate into the lower airways. Also as mentioned, in previous article, the particles in the air are classified by the aerodynamic diameter size and chemical composition. Consequently, the size, shape, reactivity, and particle density are the factors which will determine the mechanism of particle deposition.

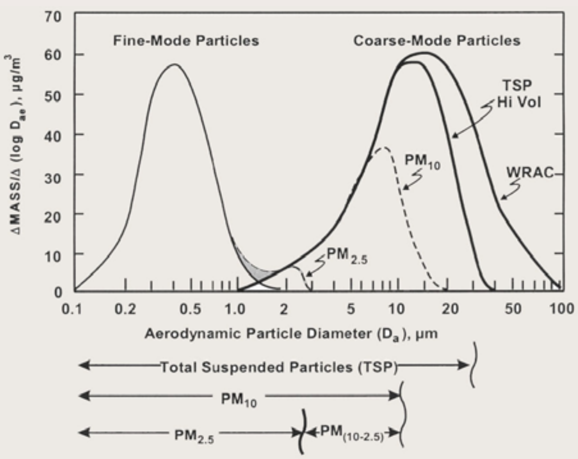

Figure1: Size distribution of fine particles and fractions collected by size-selective Samplers (US-EPA 1996).

Deposition of particles occurs by a number of processes which are categorized as primary and secondary. Primary mechanisms of deposition refer to movements dictated by size, shape and density of the airborne particles, and include settling, inertial impaction, and diffusion, also known as Brownian motion. Secondary mechanisms of particle deposition are more dependent upon the reactivity of the particles. This results in mechanisms such as interception and electrostatic attraction between charged particles and the charge on the to-be-impacted surface. These factors inevitably influence where the particles will deposit within the human body as well. Therefore, in general, it can be stated that "the smaller the particle; the more deeply will it get deposited within the respiratory tract at an increasing rate".

In the nasal-breathing mode, the cilia and the mucus act as a very effective filter for most particles exceeding 1 µm diameter. During oral breathing, particle deposition within the respiratory tract depends not only on the particle characteristics, but also on human characteristics, which resides on the fact whether the person is being active, or breathing deeply.

The particles that are most relevant in terms of human health effects are the particles which are in general less than 10 µm in diameter. These are often referred to as "inhalable particles". Such particles can penetrate anywhere within the respiratory tract beginning with the nasal passages to the alveoli, deep within the lungs according to diameter size. Table 1 exemplifies the possible penetration of particles in the respiratory tract according to their sizes.

Particle size (Range)	*Penetration of Particles*
11μm	And up particles do not penetrate
7 - 11μm	And up particles penetrate nasal passages
4.7 - 7μm	Particles penetrate pharynx
3.3 - 4.7μm	Particles penetrate trachea and primary bronchi
2.1 - 3.3μm	Particles penetrate secondary bronchi
1.1 - 2.1μm	Particles penetrate terminal bronchi
0.65 - 1.1μm	Particles penetrate bronchiole
0.43 – 0.65μm	Particles penetrate alveoli

Table1: Respiratory Penetration vs. Particle Size (Spengler et al.).

Besides the particle characteristics listed above, there is also a “human” and an “environmental” component that dictates the type and frequency of human health effects observed. The “human” component is subjugated by the exposed person’s physical characteristics, and breathing mode: rate and volume. Alternatively, the “environmental” component is influenced by local conditions, such as weather, seasons, topography, sources of particles, the concentrations being emitted, and microenvironments. To varying degrees, these three components determine the exposure effectiveness, i.e., the fraction of released material that actually enters someone’s breathing zone, and the dose actually received i.e. the concentration of PM that is actually breathed in, by the exposed person.

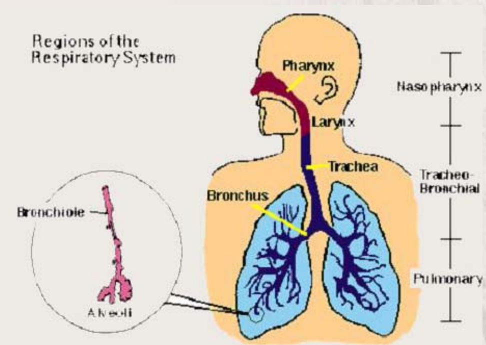

Figure 2: Relevant Regions of the Respiratory System on Exposure to PM.

The effects of inhaling particulate matter have been widely studied in humans and animals which include asthma, lung cancer, cardiovascular issues, and premature death. As the size of the particle matters it is supposed to be the main determinant of where in the respiratory tract the particle will come to rest when inhaled. Figure 2 features the relevant regions of the respiratory system exposed to PM. Thus, larger particles are generally filtered in the nose and throat and do not cause problems, but particulate matter smaller than about 10μm, referred to as PM_{10}, can settle in the bronchi and lungs and cause health problems. The 10μm size does not represent a strict boundary between respirable and non-respirable particles, but has been agreed upon for monitoring of airborne particulate matter by most regulatory agencies. Similarly, particles smaller than 2.5μm, $PM_{2.5}$, tend to penetrate into the gas-exchange regions of the lung, and very small particles (< 100 nm) may pass through the lungs to affect other organs.

As per one of the studies published in Journal of the American Medical Association, it is found that $PM_{2.5}$ leads to high plaque deposits in arteries, causing vascular inflammation and atherosclerosis — a hardening of the arteries that reduces elasticity, which can lead to heart attacks and other cardiovascular problems. Researchers also suggest that even short-term exposure at elevated concentrations could significantly contribute to heart disease.

Alternatively, the smallest particles, less than 100nm (nanoparticles), may be even more damaging to the cardiovascular system. There is evidence that particles smaller than 100nm can pass through cell membranes and migrate into other organs, including the brain. It has been suggested that particulate matter can cause similar brain damage as that found in Alzheimer patients. Particles emitted from modern diesel engines (commonly referred to as Diesel Particulate Matter, or DPM) are typically in the size range of 100 nm. In addition, these soot particles also carry carcinogenic components like benzopyrenes adsorbed on their surface.

In this respect, if we overlook the Indian scenario, it is observed that in most of the Indian cities the air quality is deteriorating at a fast pace (foe example see table 2: SPM data for different cities in India) due to increasing vehicle fleet.

City	SPM Level (mg/m^3)		
	Minimum	**Average**	**Maximum**
Mumbai	48.5	225.7	573
Kolkatta	31.5	353.6	1278
Delhi	62.5	404	1609
Chennai	26.2	122.3	516.1
Bangalore	18.5	146	632
Hyderabad	20.6	150.4	582.5
Ahmedabad	37.5	525.5	939
Pune	50	202	533
Jaipur	37	278	1067
Lucknow	224.7	374.5	535
Thiruvananthapuram	24.4	107.8	317.2
Shimla	18.8	197.5	666
Coimbatore	10	50	153
Cochin	10.5	97.15	363.2

Table 2: Air quality in certain cities of India. (The citizen's fifth report Part –II: Satistical database).

In conclusion, particulate matters are very hazardous to health and so preventive steps must be taken by the government as well as public because "Preventive action is critical for good public health management".

Do You Know?

- In diesel engines, the fuel is sprayed directly into the combustion chamber through an injector. If some of the tiny droplets of spray do not burn completely, particulate matter is formed and emitted in the vehicle's exhaust.

- An idling diesel engine uses up to four liters of fuel per hour. It also produces much higher emission levels than it would on the road using the same quantity of fuel under load.

- Particulate matter is a major component of smog and is linked to asthma and respiratory and cardiovascular illnesses.

- Health hazards caused due to suspended particulate matter would lead to premature mortality, chronic respiratory disease, weakening of eyesight, pre existing heart of lung or asthmatic patients are very much sensitive to particulate matter as these minute particles is inhaled at constant rate .

Upcoming Events

1. 15th Annual International Sustainable Development Research Conference
   Dates: 5 to 8 July 2009
   Place: Utrecht, Netherlands
   http://globalchallenge2009.geo.uu.nl

2. Global Conference on Global Warming 2009
   Dates: 5 to 9 July 2009
   Place: Istanbul, Turkey
   http://www.gcgw.org

3. 7th International Conference on the Environment and Sustainable Development: Creating Awareness to Save the Planet
   Dates: 6 to 10 July 2009
   Place: Havana, Cuba
   http://www.globalexchange.org/countries/americas/cuba/sustainable/index.html

Query Form

Name: *Designation:*

Correspondence Address:

Email:

Working Area:

Views on our Newsletter:

Suggestion for improvement (if any) :

Your Query:

BOOK-POST

To,
Dr. Gufran Beig
ENVIS Co-ordinator
Indian Institute of Tropical Meteorology,
Dr. Homi Bhabha Road,
Pashan, Pune – 411 008
INDIA

All queries and feedback regarding this newsletter should be addressed to:

Dr. Gufran Beig
ENVIS-Coordinator
Indian Institute of Tropical Meterology,
Dr. Homi Bhabha Road, Pashan,
Pune – 411 008, India
Telephone: + 91-20-25893600
Fax: +91-20-25893825
Email: pollution@tropmet.res.in
URL: http://envis.tropmet.res.in