Impact of Atmospheric Pollutant Particles ($PM_{1.0}$ and $PM_{0.1}$) On Human Health

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Abstract: ***Atmospheric pollutant particle (APP) is a vital pointer of outdoor as well as indoor air pollution. Significant causes of these particles are road dust, engine exhaust particles (diesel and gasoline), fossil fuel combustion, coal combustion (controlled and uncontrolled), and biomass burning emits smaller size particles (11-0.1 micron in diameter), which are synthetic mixes, e.g. carbons, polycyclic aromatic hydrocarbons, and metallic ions that act as gas and effortlessly blended into the surrounding air. Particles size less than 1 micron or equal to 1 micron and less than 0.1 micron or equal to 0.1 micron, known as $PM_{1.0}$ and $PM_{0.1}$ respectively. These particles are microscopic, high surface area/ mass ratio, longevity, massive accumulation potential and also furious number in the atmosphere are the major cause 0f particles exposure through the human pulmonary tract and which can affect body system including respiratory and cardiovascular system. It is possible somewhat to reduce the harmful effects of submicron particles ($PM_{1.0}$) and ultrafine particles ($PM_{0.1}$) on human health by reducing the source of gasoline-diesel engine emission by using unleaded petrol-gasoline, battery and electric power car, bus, truck and other vehicles, pollutant filter, solar cell; expansion of plantation; stopping irrelevant combustion (anthropogenic and coal), inappropriate biomass burning.***

Keywords: ***$PM_{1.0}$, $PM_{0.1}$, Sources, Composition, Accumulation potential, Effects on human health and control of atmospheric pollutant particles (submicron and ultrafine).***

l. INTRODUCTION

Air is combination of various sorts of gases like nitrogen, oxygen, carbon dioxide, carbon monoxide, sulphur dioxide, noble gases, water vapour dust and dust particles etc. Atmospheric air comprises different kinds of minute or fine mist concentrates which stay suspended noticeable all around, is called Suspended particulate matter (SPM). SPM, is an exponent of atmosphere pollution. SPMs are organic and inorganic mixture which incorporates air dust, soot, smoke, virus, bacteria, pollen, lint, algal cells and other suspended particles. Fast industrialization, excess transportation, expanding business exercises, and deforestation are the primary driver to augmentation of particulate issue level in the surrounding air, which has different adverse effects on human health mainly in pulmonary tract and cardiovascular system including bronchitis, asthma attack, respiratory inflammation, cardiac arrhythmia, heart attack and so forth. SPM behave as air pollutant, can affect (particularly Submicron and Ultrafine particulate) pretty much every organ in our body. Various useful techniques are available to separate and classify atmospheric particulate matter on the basis of their mean size. Namely ultrafine particles (diameter less than or equal to 0.1 micron), submicron particles (diameter less than or equal to 1 micron), fine particles (diameter less than or equal to 2.5 micron) and coarse particles (diameter less than or equal to 10 micron) [1]. Particulate particles size is an important factor for health issues because smaller to smallest size particles easily penetrate the biological tissue after exposure. Many researchers proved that less size particle diameter, have high potential to create health problems. As we are focusing the human health impacts of submicron and ultrafine particles on human system; so, their nature, origin, accumulation potential, harmful effects and control have been focused in this paper.

SPM behaves as gas if their diameter is less than or equal to 1 micro meter; such as submicron($PM_{1.0}$)and ultrafine($PM_{0.1}$) particulate matter [2].Smaller particles (Ultrafine and submicron) having large surface area to mass ratio(which permits inordinate absorbed materials per unit mass), which are unable to measure by their mass concentration, but it's applicable to coarse and fine particles[2].In a mixed ambient air, the total number and total surface area(TSA) decreases exponentially as the diameter of the particles increases. Oppositely, the total mass of the particle increases exponentially as the diameter of the particles increased (Fig-1). In the ambient air, particle number of $PM_{1.0}$ and $PM_{0.1}$ is higher than coarse particles and fine particles, because particle number increases with decrease in particle size [2]. Particle number concentration (PNC), is used for measuring ultrafine and submicron particulate matter in the ambient air [3]. Due to lack of ground-based submicron particles measurements from monitoring station(air), health impact on submicron particles exposure is very little to be known [4]. Despite that, in momentum time, interest on submicron and ultrafine research work has been expanded because of many evidences shows that smaller size of particulate has more harmful to human's health than PM_{10} and $PM_{2.5}$.Hazardous impact of smaller particles on human body depends on many factors such as sources of emission, levels of exposure, chemical nature and composition of the molecule, size of the particles, penetrability across the cell membranes, availability, reactivity[2][5][6][7][8][9]. After exposure through respiration, there are different ways of deposition of particulate matter in the lungs by interception, impaction, sedimentation and diffusion [10]. Particle size less than 1 micron has high tendency to entering into lower respiratory tract (exchange zone) due to gaseous nature, diffusion forces smaller particles easily spread down to alveoli, can penetrate into the biological tissue/circulatory system [8].

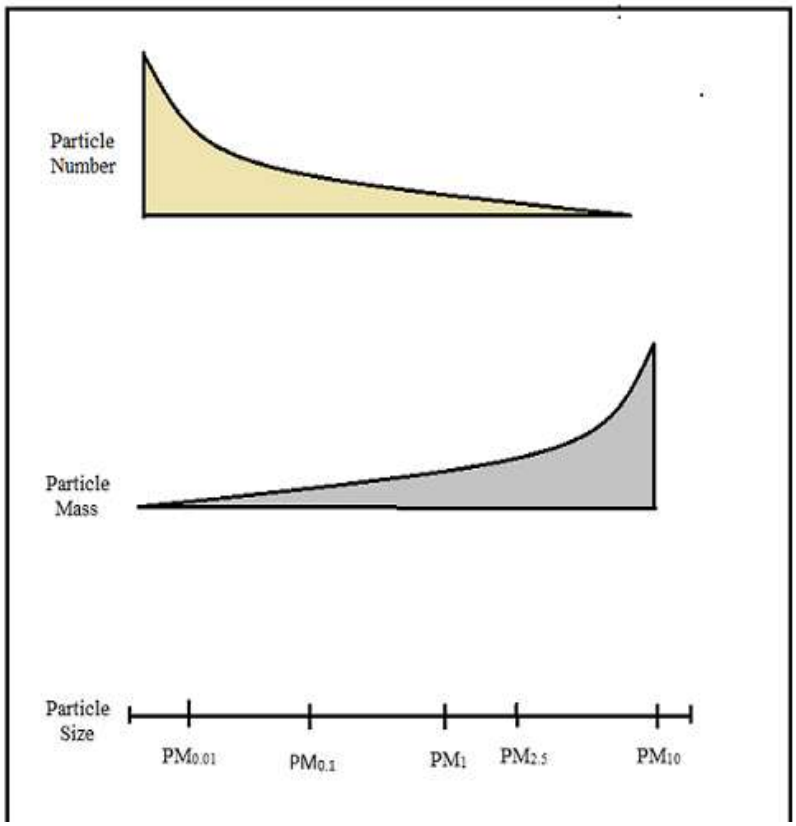

Fig- 1*: a hypothetical particulate matter ordering, according their number, mass & size*

Artificially derived submicron particles such as carbon (black and organic), heavy metals, persistent organic pollutants (POPs) are highly toxic and harmful component to human health as compared to fine particles with same chemical components [7]. In dynamic factor analysis model, relates the particles size (diameter ranging 0.01 to 0.40 micro meter) with daily mortality, have a significant association between them [11]. This is because ultrafine and sub-micron particles are able to penetrate deeply into the biological tissue mainly alveolar tissue, and harm the tissue that increases daily mortality and reduce life expectancy. European Environmental Agency (2017), predicts that decrease life expectancy approximately one year is caused by exposure of ultrafine particles (UFP) than particle size with large diameter [12].

II. **Research Methodology**

In this paper we attempt to focus the predominant impact of submicron particles and ultrafine particles on human health. In this research work, very simple research methodology is used as secondary data sources of atmospheric particulate matter pollution, impacts on human health and its control.

III. Major Sources, Composition, Life span and Travel distance

According to US Environmental Protection Agency (EPA), particulate matter divided as primary and secondary particles on the basis of their emission. Primary PM particles are straightforwardly discharge from the sources.

Contrariwise, secondary PM particles are formed when primary particles react with environmental constituents, resulting higher toxicity than primary particles. For example, fossil fuel combustion from power plant and industrial activities produces large amount of sulphur dioxide in the environmental air, whereas sulphur dioxide reacts with environmental constituents to form secondary particles, sulphate. Furthermore, secondary PM particles are formed, when primary PM particles reacting with environmental water vapour, molecular oxygen, hydrocarbon by series of chemical reaction, make more complex mixtures such as photochemical smog, ground-level ozone, acid rain, nitrogen oxide, which forms yellow clouds.

Table 1 shows that both submicron and ultrafine particulate matter principally originate, directly emission from traffic related emission (road dust, gasoline and diesel engine exhaust), fossil fuel combustion (fuel- oil combustion, residual- oil combustion, controlled and uncontrolled coal combustion), anthropogenic combustion (tobacco smoke, plastic burning), biomass burning, and also naturally (mineral dust, sea salt). Submicron and ultrafine particulate particle comprise by a large number of chemical compounds, including elemental carbon (EC), black carbon (BC), organic carbon (OC), particle bound water, poly aromatic hydrocarbons (PAHS) and metals. In contrast to ultrafine particles, submicron particles stay longer (days to weeks) in the ambient air and can travel long distances (100 to 1000km) from sources of origin due to long atmospheric half-life and late removal process.

Table-1: pm $_{1.0}$ and pm$_{0.1}$ – major sources, composition, life span and travel distance.

Sources	**Submicron particles (PM $_{1.0}$).**	**Ultrafine particles (PM $_{0.1}$).**
Emission from heavy traffic	Road dust, gasoline-diesel exhaust.	Road dust, vehicular emission from gasoline and diesel engine.
Fuel combustion (Fossil)	Fuel oil combustion, residual-oil combustion, coal combustion (controlled & uncontrolled).	Power plant, fuel oil combustion.
Anthropogenic combustion	Tobacco smoke.	Tobacco smoke, plastic burning.
Biomass burning	Softwood, hardwood, Secondary Organic Aerosol (SOA).	Cooking oil, electric air heater, vacuum cleaner, candles, gas stove.
Natural sources	Mineral dust, sea salts.	
Composition	EC, particle bound water, metals (Fe, Mn, V, Ni, Cu, Zn, So_4^{2-}, No_3^-, NH_4^+, Ca^{2+})	EC, BC, OC, PAHs, Metals (So_4^{2-}, Pb, Cd, Ar, Cr, V, Ni, Se, Si, Al, Fe, Zn)
Atmospheric half life	Days to weeks	Minutes to hours
Travel distance	100 to 1000 km	1 to 10 km

[EC- Elemental Carbon, BC- Black Carbon, OC- Organic Carbon]

Source-US Environmental Protection Agency [13],[14]

IV. **Accumulation Potential of different sizes Particulate Matter (PM) in the Human Respiratory Tract**

As because respiration is the primary route of particulate matter expose, Pm can be deposit in the respiratory tract according to their sizes. Figure 2 shows particles with 1.1 to 0.43 micrometre in diameter stays within the terminal bronchioles and alveoli. Many studies have shown that submicron and ultrafine particulate matter can easily deposited in the inner part of the respiratory tract especially gas exchange zone (i.e. alveoli), which restrict gas passaging or can even penetrate the alveolar epithelial cells, or can mixed into the circulatory system or may effect whole organ in our body. It is recognized that the effectiveness of these particles exposure largely influenced by physical characteristics (i.e. respiratory rate, breathing mode, lung volume) and local conditions (i.e. microenvironment, weather, seasons, geographical position, sources and concentration of particles) [8][15].

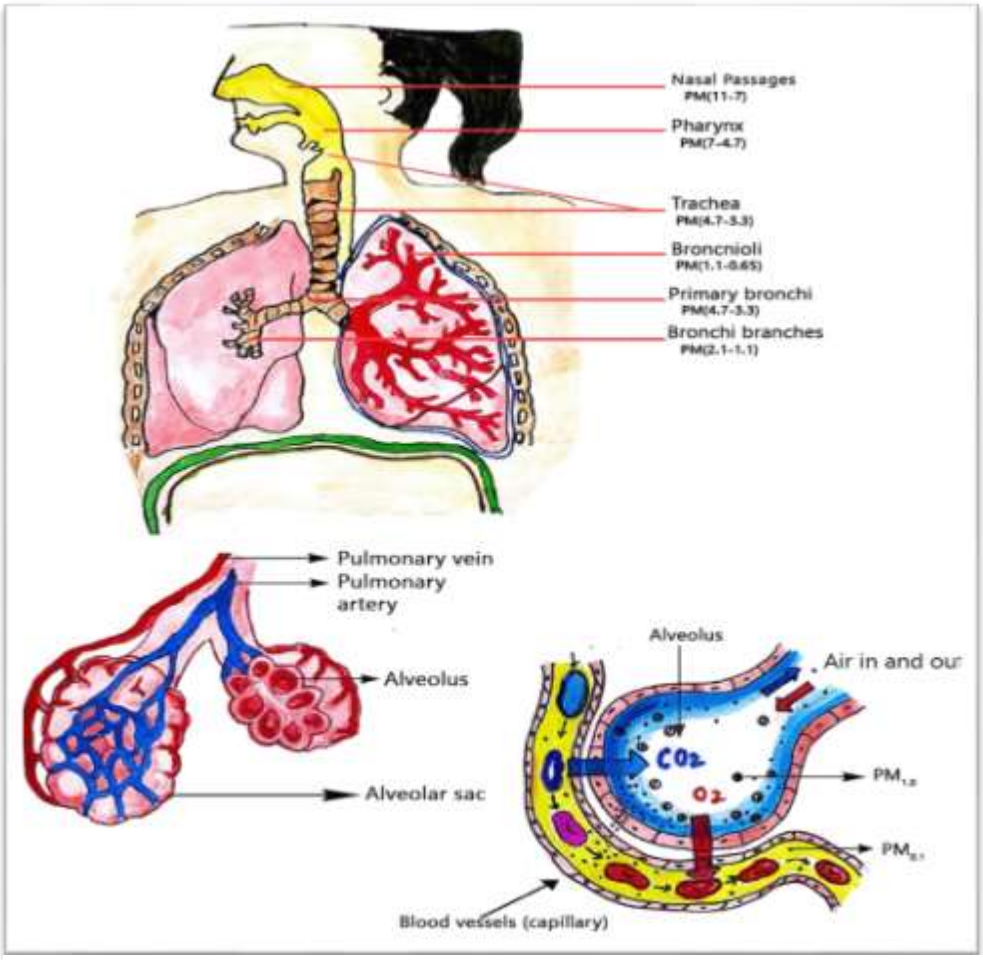

Fig- 2*: Accumulation potential of different sizes particulate matter (pm) in the human respiratory tract.*

V. **Effects of Submicron particulate matter ($PM_{1.0}$) and Ultrafine particulate matter ($PM_{0.1}$) on Human health**

Various experimental studies have shown that submicron ($PM_{1.0}$) and ultrafine particles ($PM_{0.1}$) are more prone to adverse effects on human health than fine and coarse particles, as smaller particles can freely cross the alveolar wall and mix easily in systemic circulation [18]. According to many researches it is also evident that ultrafine particles ($PM_{1.0}$) are much more toxic to human health than particles ($PM_{0.1}$). But we know from this study both particles are directly involved in adverse health impact on human health including respiratory system as well as cardiovascular system. More research is needed on both these particles in the future because many studies have not been able to come to a significant conclusion due to lack of data sources.

Table-2: list of adverse health impacts of submicron particles ($pm_{1.0}$) & ultrafine particles ($pm_{0.1}$) exposure.

EFFECTS OF $PM_{1.0}$ & $PM_{0.1}$ ON HUMAN HEALTH		
PM	HEALTH IMPACTS	REFERENCE
Submicron Particles ($PM_{1.0}$)	Induce cytokine production (IL-4, IL-5 & IL-13) leading to pulmonary inflammation during exposure to diesel exhaust particles (DEPs).	[5][9]
	Induce lipid peroxidation in epithelial cells(bronchus).	[9]
	Increased risks at hospital admission associated with Chronic Pulmonary Disease (COPD) & pneumonia in cold season.	[4]
	Increased risk of cancer when exposure to PAHs (Poly aromatic Hydrocarbon) associated $PM_{1.0}$	[19]
	Increased risks of daily emergency hospital visit.	[20]
Ultrafine Particles ($PM_{0.1}$)	Alveolar inflammation- short term exposure to DEPs.	[2][12][21]
	Mucociliary dysfunction in the respiratory tract leading to pulmonary illness associated with cough, bronchospasm and asthma.	[2]
	Increased risk of COPD	[2]
	Children eczema exposure to high level of PAHs	[2]
	Increased risks of Ischaemic Heart Disease (systemic inflammation & coagulation abnormality)	[2][14][21]
	Short term exposure leads to early atherosclerosis	[2][21]
	Short term exposure to Hypertension (increased blood pressure) & Tachycardia (increased heart rate)	[2][12]
	Loss of sympathovagal tone	[2]
	Changes in ECG (ST segment depression of >0.1 mv)	[2]
	Decreased blood plasminogen and thrombomodulin level	[2]
	Increased levels of C-reactive protein (CRP) & serum amyloid	[2]
	Cardiovascular disease associated with Myocardial infraction & heart failure during long term exposure of $PM_{0.1}$	[2]
	Increase ROS production, oxidative DNA damage, exposure to PAHs associated $PM_{0.1}$	[2][21]
	Cellular damage, Mitochondrial change & Lipid peroxidation	[21]
	Oxidative stress	[12][21]
	Affect brain & its developments after short term exposure to $PM_{0.1}$	[2]
	Increased sympathetic nervous system activity, decreasing Non-epinephrine after exposure to O_3 associated $PM_{0.1}$	[2]
	Increased mortality rate	[2][11]
	Metal & polymer fume fever after short term exposure to metal fume & fluorinated polymer fume respectively	[2]
	Increased risks of medicine use & hospital admission	[2]
	Increased chance of Diabetes mellitus & metabolic illness	[2][12]
	Low birth weight after exposure ultrafine particles in heavy traffic area	[2]

The various adverse effects of these particles are shown in table 2. Adverse effects of Submicron particles depend on levels of exposure (i.e., Short- and long-term exposure), chemical nature and composition of the molecule, size of the particles, penetrability across the cell membranes, availability, reactivity, particle charge also. Short term exposure to Submicron particles is associated with alveolar inflammation, lipid peroxidation in bronchial epithelial cells, increased risks of Hospital admission related to COPD and pneumonia in cold season and daily emergency hospital visit. Long term exposure to PAHs associated submicron particles increased the risks of cancer. As opposed to submicron particles, the ultrafine particles have adverse effects on different organs in addition to respiratory system and cardiovascular system which is known from various experimental and health studies. In the respiratory system, short term exposure to DEPs associated ultrafine particles leads to alveolar inflammation; and conciliar dysfunction results cough, asthma, bronchospasm; increases risks of respiratory morbidity and mortality. The major adverse effects of ultrafine particles on the cardiovascular system are ischemic heart disease (systemic inflammation and coagulation abnormality),

early atherosclerosis, changes of ECG pattern, tachycardia, hypertension, increases risks of cardiovascular morbidity and mortality. Long term exposure of ultrafine particles causes myocardium infraction and also heart failure.

VI. CONTROL

It is not so easy to control, but it is possible to reduce it somewhat less by shut down the source of traffic related emission by using unleaded petrol, solar energy, battery electric vehicles (BEVs), pollutant filter; stopping irrelevant fossil fuel combustion, irrelevant anthropogenic combustion, inappropriate biomass burning.

Due to this ambient air pollution, all the part of nature become hamper such as the forest, a complete lifestyle which is totally depend on forest. To conserve all these, Ministry of Environment and Forest (MoEF), Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) has made few authentic legislations. These are, -

- To establish National Green Tribunal (NGT), Central government build National Green Tribunal Act on 2010.
- Indian government take his first attempt in 1981 to prevent the air pollution as well as to control the level of emitted particle through Air (Prevention and Control of Pollution) Act.

Georg Jager and Chiara Letter has suggested that, *Pinus pinea, Acer pseudoplatanus, Cornus mas* etc. are the example of some tree which can absorb higher amounts of particulate matter. They have been worked on these trees and got a meaningful result i.e. the Pm concentration on 1/1/2017 is 131 but after planting these trees the value was reduced to 46 (noted on 31/12/2017) [22].

VII. Acknowledgement

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