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Aerosols Pollution and its Effect on Climate, Human and Environment

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Abstract: The aerosol particles are very tiny particles which are not visible to necked eyes. These particles have different sources of emission i.e. anthropogenic and naturals, but by comparing the post and pre industrialization period, it is concluded that the post industrialization activities are more responsible for the aerosol pollution. These aerosols are stratified in different layers of atmosphere and this stratification is depends on the aerosol size and chemical composition, these characters are also responsible for its stay time in atmospheres on the basis of given characteristic aerosols has certain adverse effect on environment, climate and human health. The aerosol pollution can causes imbalance in hydrological cycle by interacting with clouds, it also disturb biogeochemical cycles which leads to adverse impact on climate and environment. The aerosols pollution are also reported for many dieses related to respiratory system, lungs, heart and brain trouble in human beings, mostly in developing countries which have low level of technology for fuel emission and basically depend on the raw fuel for their daily purpose. Satellite based study of aerosol played a crucial role to understand the nature, distribution and its effect on climate, environment and human health.

Key words: Aerosols, Climate, Environment, Human health, Hydrological Cycle, Biogeochemical cycle.

1. Introduction:

Changes in global climate /weather is considering due to industrialization. Increasing in emission of green-house gases and aerosol, were believed to play a vital role in global climate change. Atmospheric aerosol is suspensions of fluid, solids, or blended particles with complex chemical composition, size and distribution. Aerosols are stable in atmosphere for few second to several months. The term aerosol includes both the particulates matter and suspending gasses. Aerosols are of distinguish variety due to their various sources and unsystematic development systems. Aerosol particles are either radiated directly to the environment or formed in the environment from forerunner gases, those aerosols

which are directly emitted to the atmosphere are called primary and those emitted in environment from forerunner gases are called secondary Aerosol (Myhre *et al,*2013).Pattern of Aerosol effect on atmosphere shows that Aerosol particles assimilate and diffuse sun radiation power, it also reduce the precipitation. Aerosols are generated by both the mediums natural and human's activities. Aerosols which are generated by wind erosion of surface soils by producing dust particles, condensation of sea and salt water, volcanic eruption are natural medium , while the anthropogenic sources are agricultural activities automobile exhaust and imperfect combustion of fossil fuels in power plants (Kalliat *et al,*2009). Aerosols have various impact on living hood of human being in both the way directly i.e. health and environmental effect and indirectly due to its impact on air quality and climate change (Cao, 2017). These particles have the efficiency to increase the earth temperature and disturbance in atmospheric energy balance (Lin *et al*, 2016). Aerosol emitted in environment due to anthropogenic fuel ignition has harmful effect on both human health and atmosphere. Upgrading and advancement in fuel ignition technologies will improve the net impact on both atmosphere and human health. It is also acknowledged by researchers that there are lots of potentially health hazardous organisms present in atmospheric aerosols that could significantly harmful to human health and causes fibrosis, blockage of lungs etc. diseases (Ren-Jian *et al,*2012). The health impact of aerosols have both short-term acute symptoms which leads to disease like asthma and bronchitis, and long-term chronic irritation and inflammation of the respiratory track, which can efficiently lead to cancer (Ju Oh. *et al,*2020).

2. Understanding the Aerosols

The term Aerosol incorporates both the Particulates matter (PM) and suspending gas. Particles size from about 0.002 to more than 100 μm. Aerosols occur in both section of atmosphere i.e. troposphere and the stratosphere, but there are noticeable differences in the size, chemical nature and other properties of the aerosols that occur in these atmospheric layers. Numerous research projects are underway for the accurate characterization and classification of aerosols (Prakash *et al,*2020).

Source of Aerosols:

Aerosols present in atmosphere are formed by physical, chemical and biological process generally takes place over the earth's surface in the atmosphere. (Tomsai and Lupi, 2017) proclaim three major sources of Aerosols on the base of their formation mechanism generally present in atmosphere.

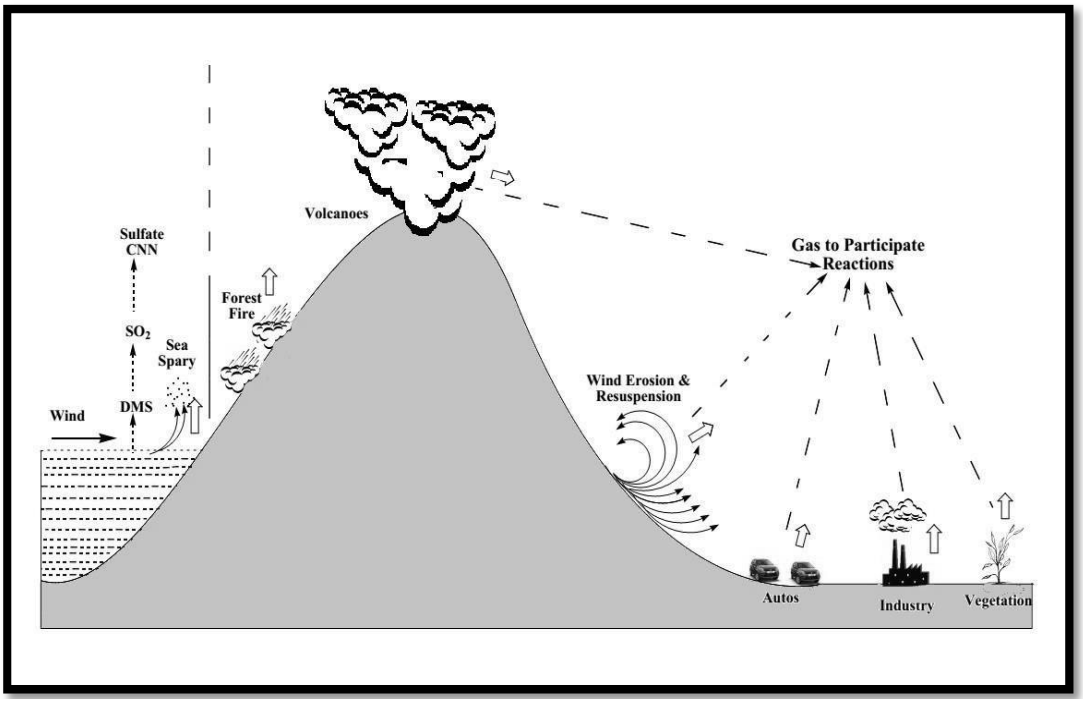

Figure 1 Source of Aerosol

(1) Bulk to Particle formation (b-to-p) in other words transformation from mass to-molecule there are mainly three approach are studied (A).Mineral's particles obtain from the earth's surface (wind blow), (B). Formation of the fluid/liquid base material consist of normal marine water/ salt water resources deposit, (C) particulate material is formed by biological stuff (mostly plant trash and dusts dead decay creatures) . It is clear that variety of physical, substance, and organic forerunners are major ingredient in all these b-to-p transformation process for the division of the mass material into particles before its discharge into the environment(2). Gas to particle (g-to-p) conversion (Particle formed from gaseous state) in this process particle formed by the self-assembly or organization from gaseous state. In this process physical and chemical both the reactions takes part, very small particles are initially formed (3). In this process combustion at high pressure takes place and support development of particles with shape and chemical character to be identify as Aerosols.

Aerosol Type	Source Strength ($TgYr^{-1}$)	Natural MainSource activities	Source Strength ($TgYr^{-1}$)	Anthropogenic Main Source activities
Sulfates (as $HS0_4^-$)	104 (59-182)	Fossil fuels and smelting	49 (24-101)	Di methyl sulphide and H_2S from oceans, land biota, and soils
	3.2 (1.5-9)	Enhanced emissions of Di methyl sulfide associated with stronger winds and higher temperature from climate change	18 (8-40)	Volcanic SO_2
Organic Carbon	20 (10-30)	Fossil fuels, Outdoor cooking	14 (8-40)	Photochemical conversion of terpenesto condensable
	6 (3-17)	Enhanced emissions of terpenes from higher temperature due to climate change		Products and primary biogenics
Black carbon	7 (4-11)	Fossil fuels, outdoor cooking	** (not studied)	Biomass burning**
Smoke	70 (50-90)	Biomass burning; smoke is largely composed of organic and black carbon and is therefore, often included in those categories.	3 (2-4)	Natural fires
Nitrates (as $N0_3^-$)	14 (10-20)	NOx from biomass burning, fossil fuel, and aircraft; agricultural soil NOx	4 (2-4)	Lightning, Natural Soil, and Stratospheric NOx
Ammonim Nitrates (as $NH4^+$)	19 (11-34)	Nitrogen fertilizer; domestic animals; human emissions Biomass burning; fossil fuel and industry	12 (6-26)	Natural soils, Wild Animals, and Oceans
Sea Salt	67 (23-126)	Enhanced wind injections associated with climate change	88 (30-165)	Formation of jets and bubbles from wind
Dust $r < 1$ µm	200 (100-300)	Agriculturally disturbed lands and increased desertification	200 (100-300)	Wind-blown dust in deserts and other arid, susceptible areas
	20 (10-30)	Dust associated with enhanced winds and arid areas due to climate change		

Table 1 Aerosol Source and Source Strength

*In brackets the estimates source influence is predicted for 2001 (Source: Joyce *et al,*2001)

**Black Carbon anthropogenic source 7.5 $TgYr^{-1}$(Source: IPCC, 2001)

Type of Aerosols:

Primary aerosols are the atmospheric particle which are directly release or introduce into the atmosphere while the Secondary aerosols are produced in atmosphere by chemical reaction on primary aerosol

Primary Aerosols derive from natural sources : major natural source of primary aerosol particles are: Sea-Salt particles, Mineral dust (when the wind blown over desert and semiarid surface), Biogenic Aerosols (plants and animals release solid and liquid particle in atmosphere for example forest fire smoke biomass burning smoke is emitted into the atmosphere), Volcanic Dust in the Troposphere due to volcanic eruption its emitted both gasses and dust, Cosmic Dust, Asteroidal dust, Kuiper belt dust, and interstellar dust

Primary aerosol release from anthropogenic origin can be distinguish into three following classes: (a) Industrial dust, i.e. transportation, waste incineration, coal combustion etc. (b) Particles from fossil fuel combustion that include an important fraction of carbonaceous (soot) aerosols (iii) particles from waste and biomass burning like carbonaceous particles results from bio fuel, agricultural, and uncontrolled biomass fire

Secondary Aerosols of Natural Origin: Naturally secondary aerosols originate in the atmosphere as a result of g-to-p conversion process like natural sulfate particles raised from troposphere i.e. SO_2 and sulfur compounds sulfate aerosols are produced by chemical reactions which takes place in the atmosphere involving gaseous precursors, natural nitrate particles originated from troposphere NOx produce from biological process or burning of biomass, agriculture resources etc. organic aerosols comes from biogenic volatile organic compounds it's involve g to p conversion e.g. Biomass combustion. Sulfate Particles from Volcanic eruption of $SO_2$and placed over Stratosphere region

Secondary aerosols of anthropogenic origin i.e. oxidation of anthropogenic SO_2 emissions from coal burning, secondary particles from NOx and condensation of gaseous HNO_3(Tomsai and Lupi. 2017)

Size of Aerosols

The sizes of atmospheric aerosols is depend on its radius (r) it is scale up to five categorize from 0.001 μm to 100 μm on the base of their sizes and formation mechanisms aerosols are categorized in three major mode, Nucleation mode (0.001 μm< r < 0.1 μm), e.g. Shoot, Sulphuric acid, and Bio organic based aerosols

Accumulation mode (0.1 μm< 1.0 μm) e.g. Ammonium sulphate produce droplet, Biomass smoke, aerosols in the accumulation mode are generally produced by the coagulation of smaller particles and by the heterogeneous condensation of gas vapour onto existing aerosol particle.

Coarse mode (r > 1.0 μm) e.g. Pollen, Sea Salt and Dust, Marine origin based aerosols. Size of Aerosols has major effect on its stability in atmosphere,

climate change and human health.Aerosol presence or quantity in the environment is typically measure through its mass concentration or by using an optical degree, Aerosol optical depth (AOD). AOD is assets vertically entire height of atmosphere, fraction of incident light either scattered or absorbed via airborne particles(Rajesh, 2013)

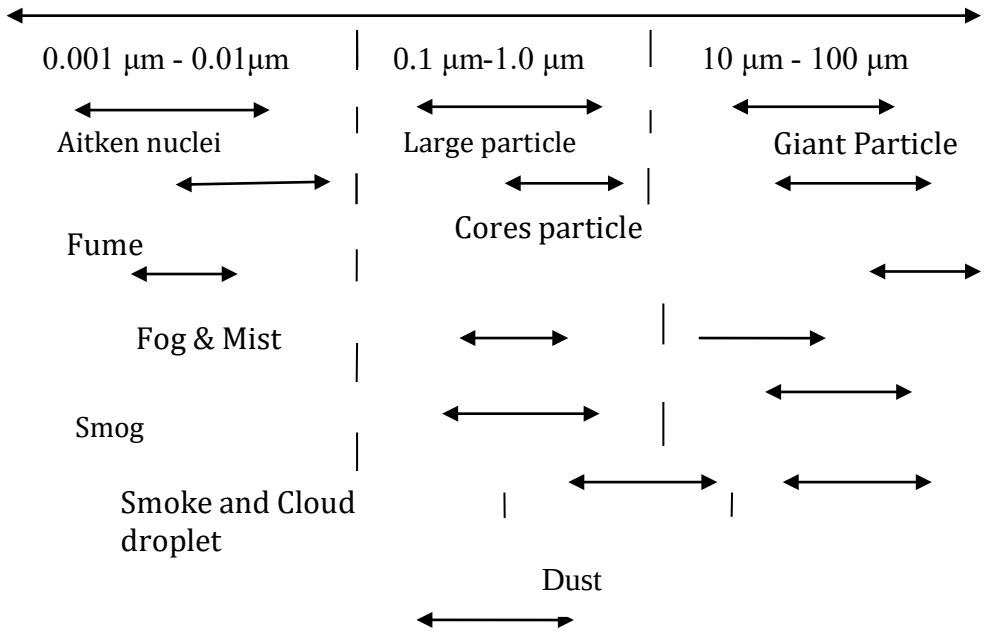

Figure 2 Size of Aerosol

Aerosol size distribution

Distribution of Aerosols in atmosphere is depends on particle diameter. Size of aerosol depends on its formation process. Dispersal of aerosols in atmosphere is characterising by- (i)Junge power law size distribution (ii) Lognormal particle size distribution (iii) Modified Gamma distribution (iv) Zold distribution.

Shape and Density of Aerosol

Aerosols are of different shape and densities, thus it is compulsory for researchers and scientist community to standardize particle size that revel its function system in a fluid such as air. The term "Aerodynamic Diameter" has been developed by aerosol physicists in order to provide a simple means to give basic method for arranging the extents of particles having various shapes and densities with a solitary measurement. The aerodynamic diameter is the diameter of a spherical particle having a density of 1 gm. /cm^3 that has the same inertial properties (i.e. terminal settling velocity).Aerosols estimations test are performed at every conceivable location in the atmosphere during the last two decades most of the observed data indicate Aitken nuclei observation, which pointed that the nuclei source of formation is dominate, but most of the pollution-related study outcomes shows that samples having variable and often uncertain large particle cut offs. Although later the successfully distribution measurements been made so that the relative concentrations of the different modes in the distribution under various conditions can be determined (Whitey, 2007)

3 Impact of Atmospheric Aerosols on Climate and Environment

The influence of Aerosols on climate change is burning topic for research and study as well as numbers of researchers and scientist are working continuously on it and concluded in their studies that aerosols have the ability to change the precipitation module as well as temperature also. The influences of atmospheric aerosols on cloud properties (i.e. aerosol indirect effects) strongly depend on the aerosol CCN (Cloud condensation nuclei) concentration, which can be effectively predicted from detailed aerosol size distribution, mixing state, and chemical composition by using Kohler theory. As expressed by the Mie (1908) Scattering theory, aerosols associate strongly with the sun oriented (shortwave) radiation and weakly terrestrial (long wave) radiation. As a result of such strong associations, aerosols initiate significant dispersing and assimilation impacts on the radiation budget plan of the earth. This scattering and assimilation of solar radiation affect the atmospheric system albedo and increase the temperature of earth (Haywood and Boucher, 2000, Bellouin *et al,*2003). Intergovernmental Panel on Climate Change (IPCC, 2007) reported that secondary organic aerosols (anthropogenic and biogenic) source is responsible for increase in the global temperature. Sulfates, Nitrates and Organics aerosols due to anthropogenic changes in their emission source and human activity takes part in it and increase

global temperature and also influence the hydrological cycle (Lin *et al,* 2016).Composition and properties of aerosol is very important as they strongly influence their role in counteracting global warming (Colbeck and Lazaridis, 2010).

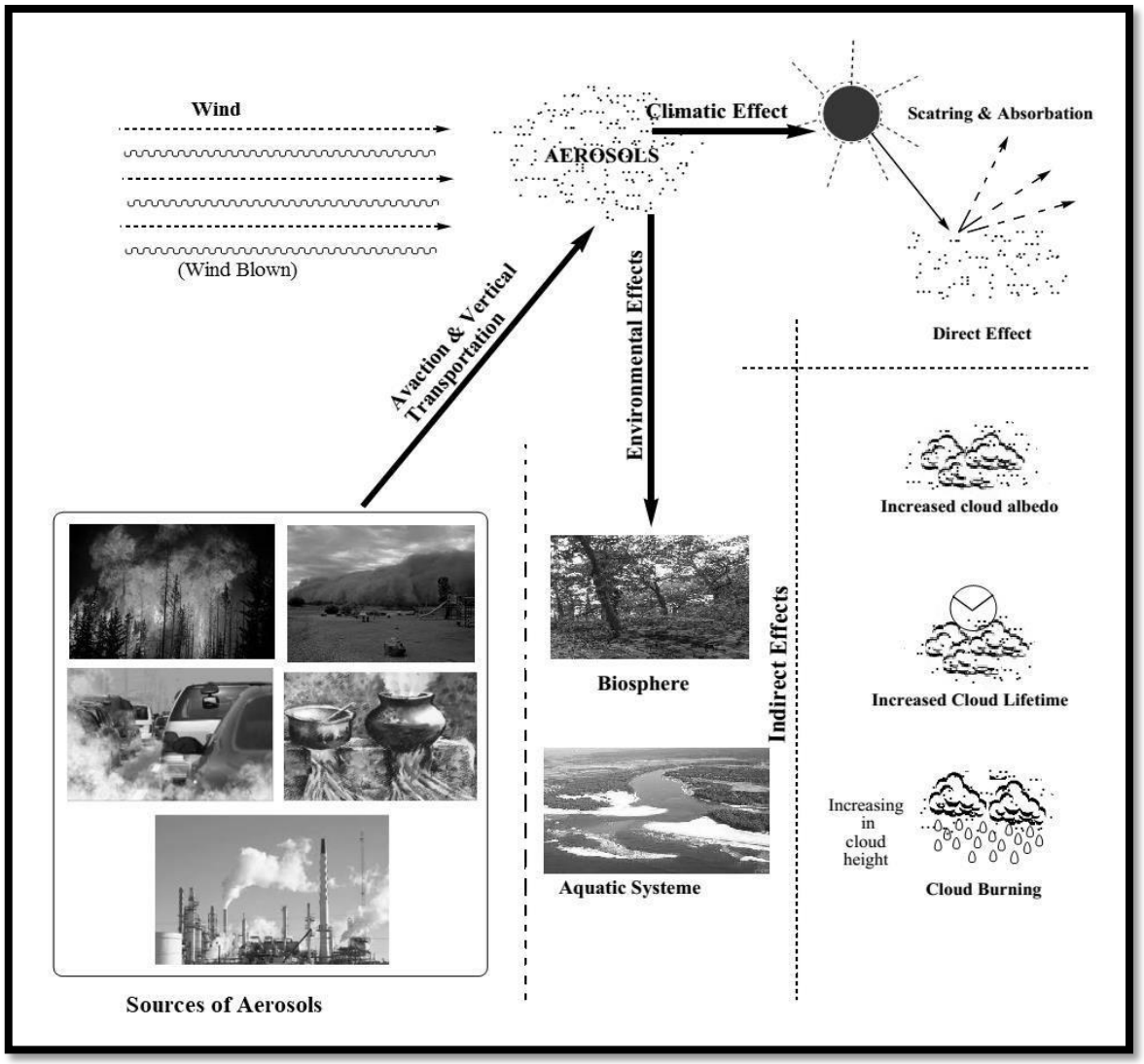

Figure 3 Impact of Aerosols on Rain fall and Climate Change

4. Impact on Rain fall and Climate Change

To understand the cloud and precipitation procedure occurrence from micro-scale to cloud-scale and meso scale, also their connections with radiation and surface processes Cloud-resolving models (CRMs) have been used. CRM provide refined and reasonable demonstration of cloud microphysical processes and can practically well resolve the time evolution, structure, and life cycles of

clouds and cloud systems. CMRs is also helpful to understand the relation between cloud, outgoing long wave (cooling) and incoming solar (heating) radation ocean and land surface process(Tao *et al,*2014).Interaction of Aerosol with cloud is an important factor that may influence the precipitation cycle of the affected area and make drastic changes in the environment. The role of aerosols to produce disorder in cloud's properties and precipitation module of the affected area's environment is absolutely different for the different types of clouds and principally regulated by atmospheric dynamics and thermo dynamics. Twomey effect demonstrate how cloud condensation nuclei (CCN), may increase the amount of solar radiation reflected by clouds and reducing droplet size possibly by anthropogenic aerosols in a constant liquid path and this may directly influence the precipitation module of the area (Twomey, 1977). Fan *et al* (2016) also discus some various indirect effects of aerosols on cloud, aerosols are responsible for increasing of cloud lifetime and suppress rain and both are regulated by reduced droplet size and narrower droplet spectrum these phenomena are account as radiative effect. Aerosols also have significant microphysical effects on clouds, cloud carbon nuclei (CCN) induce moderate change in cloud drops which convert into raindrops by nucleating small drops (which are slower to combine to raindrops) in large amount. This impact alter precipitation module and slow down rain and the polluted region would suffer from reduced rainfall. Satellite study over Australia's urban and industrial area reported (Impact of CCN) air pollution plumes suppress precipitation module Rosenfeld *et al,* (2008).Dave *et al,*(2019) concluded in his study about Indian monsoon that aerosols influence the cloud related properties in distinct ways in poor and good both monsoon periods, when monsoon rain fall is noted to low or poor level it is observed that aerosols present in atmosphere associate with smaller cloud drops, shallower cloud heights, and less cloud-ice formation this led to poor rain fall. In case of good monsoon (higher level of rain fall) high concentration of aerosols associate with larger cloud droplet size, high clouds, also large ice cloud formation are found and disturb monsoon module in Indian region. Scannell *et al,* (2019) discuss the impact of aerosols over east and west African rainfall system and predicted that anthropogenic aerosol change have been potentially linked to the East African rainfall, while in past many studies reveals that shifts in African rainfall due to shift in the tropical rain bands while the aerosols concentration is responsible for it. The impact of aerosols over the central European climate is also follow the same pattern as in the other part of the world. Aerosol impact on precipitation is mostly altering mountain area's rainfall. The shallow clouds over mountain terrain attract with large aerosol loding in atmosphere by the high radiative forcing cloud condensation nuclei formation and suppress rain Barthlott and Hoose (2018).The hydrological cycle of any area play an important role over the area environment and it direct influence the socio economic structure of the area because the rain fall is the main natural resource for the agriculture production and changes in rain fall pattern can chance the climate which leads other serious environmental problems it also have direct

serious health hazardous to the human health.In a study based on Pine forest in Europe Kulmala *et al,*(2004)suggest link between forest ecosystem functioning,

limate change and aerosols that globally increasing in temperature and carbon di oxide (CO_2) emission will encourage the process of photosynthesis and this will lead to growth of forest biomass, the increasing in forest biomass will also increase the emissions of non-methane biogenic volatile organic compounds and this will increase in emission of organic aerosols production. Aerosols have direct connection with Earth's atmosphere and environment as they play important role in atmospheric radiative balance. This have directly effect on hydrological cycles, and the biogeochemical cycles of some main elements, like sulfur, nitrogen, iron, etc. and these biogeochemical cycles influence ecosystem. The unbalancing in biogeochemical cycles has the efficiency to acidify soil system and also marine ecosystem (by providing soluble iron to marine phytoplankton and imbalance marine ecosystem as iron is working as macronutrient for planktons) (Cao, 2017)

4. Impact of Aerosols on Human Health

World health organization state that asthama, stroke, heart disease and pregnancy problem are cause mainly due to the poor air quality Bave *et al,* (2019). Among the other component of air aerosols are major component. When the air is polluted by aerosols in common by heavy metals dust, incomplete or improper combustion of fossil fuel or bioaerosol it becomes hazardous to human health because aerosols can introduce to the body mainly through the respiratory system and then enter to the human blood circulation quickly. It cause to an increased risk of cardiovascular and pulmonary diseases while in the USA and Europe mostly cases are reported cardiovascular and pulmonary diseases due to aerosol toxicity (Zwozdziak *et al,* 2011).Aerosols are the very important constituent of the atmosphere and they have direct effect on the environment quality, visibility and health issues due to their heterogeneous chemical reaction in atmosphere as they are mainly consist of sulphate, nitrate, ammonium, organic carbon, elemental carbon, and mineral elements, whereas the important atmospheric heterogeneous chemical reactions takes place over the surface of the aerosol particle. Size of aerosol is responsible for spreading of disease, accumulation and absorbing of aerosols in the human body is depend on its size, it is noted that aerosols emitted through biomass have highest optical density and because of their size they easily accumulate and absorb to human body this is also a reason that developing countries of Africa, South of America and East Asia is highly affected by disease spared through aerosol pollution (Lajili, 2018). Bhardawaj and Burney (2018) mention in their article related to impact of sand and dust particle on human health in case of cognition disorders that brain can also affect by aerosols while this affect is depend in aerosol's size. Usually the size of aerosols are ranged from 10^{-3} to 10^{-2}µm, on the basis of particle size aerosols are classified as Total suspended particle (< 100µm), Floating dust (< 30 µm), PM_{10} (<10 µm), $PM_{2.5}$ (<2.5 µm)whereas PM_{10} and $PM_{2.5}$ are known as

halable particle these particles are most threatened to human health byinhaling these aerosols particles inhales by people through respiration while their accumulation and position in the respiratory system is depend on its diameter or size. Minor particle comes in contact to larger particle's surface area and generate chemical reaction in the human body and causes fibrosis of the lung and these minor particles in the atmosphere associate with microbes, which can simply cause infectious diseases that can gradually create blockage in the lungsmetal powders emitted from smelt blast furnaces and 3,4-Benzypyrene can cause cancer (Jian *et al,*2012).Residential solid fuel like wood, charcoal, agricultural residue, animal waste, and coal are used in most of the regions of the developing countries as their major fuel source they burn at low combustion efficiency systems like stoves or in open and resulted in extensive aerosol emission. This source aerosol emission have considerable adverse impacts on human health as they are responsible for diesis like lung cancer as well as cardiopulmonary disease and mostly mortality is reported in East Asia followed by West Asia, Russia and Europe (Butt et al, 2016)

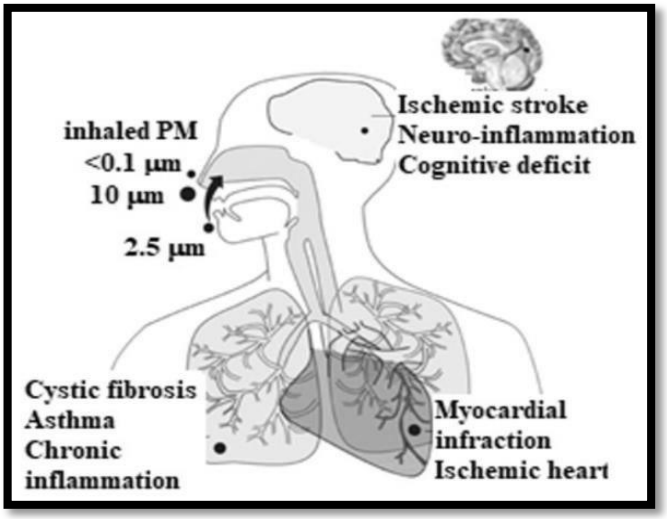

Figure 4 Impact of Aerosols on Human

Figure Sources**:** : M. Lajili (2019)

In a study of size-resolved respiratory particle-deposition model with global size-resolved aerosol model to calculate the variability in particle deposition in the respiratory tract due to difference in ambient PM (Particulate matter) size distributions and revealed that the ratio of deposited PM mass in the trachea bronchial and alveolar noted 20-30% variability due to local/regional difference in ambient aerosol size distributions PM deposition in the body, which may lead to variability in the health response from exposure (Kodros *et al,*2018). Bio aerosol along with the different constitute aerosols can have a major impact on human health as well as infectious diseases, allergies, acute toxicity and cancer. Numerous bacterial infectious diseases such as *Legionellosis*,

Tuberculosis, Anthrax, etc., are reported due to chronic and even short time exposure to bio aerosols. This is for the reason that some aerosols, consist of bacteria, virus, fungi, pollen, and stay in the atmosphere moreover have a long atmospheric residence time, particularly bacteria including surviving and non-surviving bacteria primarily due to the coarse particles (Particulate Matter 10–2.5mili micron) in the atmosphere (Oh *et al,*2020)

5. Future work and approaches

Uses of satellite study: In recent years number of satellite agencies of different countries from all over the globe working in the field of aerosol scienceto predict its nature effect on atmosphere and human health but there is requirement for more study and produce most accurate data and build-up of appropriate model to get absolute result, so its need more study in this field

Making of more centres for Aerosol study: As it is concluded in upper section that more and appropriate study is need so it is most important to develop more centres across the world for aerosol study

Reduce in uses of fossil fuel: All researchers and scientist are agreeing that the burning of fossil fuel is the key factor for the development of aerosol pollution so there should be major steps has been taken for the reduction in use of fossil fuel Using upgrade technique for the ignition of the fossil fuel: by comparing pre and post industrialization periods the outcome revel that fossil fuel ignition technique should be upgraded and such of ignition module should be develop which produce very low to zero aerosols particles

Prohibited the ignition of raw fuel i.e. Wood etc: It is reported that mostly in developing countries the raw fuel is use for different uses i.e. household and others like in farm land farmers are used to burn their farm waste which is also responsible for the aerosol emission in atmosphere, so it should be stop by local authorities

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