



EFFECT OF PARTICULATE MATTER (PM) ON CLIMATE, PLANTS, HUMAN HEALTH AND ECOSYSTEM

Science

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ABSTRACT

The work reported in this paper is part of a much larger research project on airborne particulate matter. These particulates have now become a matter of serious concern in the global environment, since not only can they have substantial negative effects on human health but they can also influence precipitation levels, the earth's climate and the ecosystem. Furthermore, the deposition of these particles on vegetated surfaces can adversely affect plant and animal life. The size, chemical composition, and origin of these particulates vary greatly. The effects of these particles have been comprehensively studied and reviewed in this paper with their associated environmental impact.

KEYWORDS

Particulate matter, effect on human health, effect on climate, effect on ecosystem, deposition

INTRODUCTION

Particulate matter is also known as atmospheric aerosol particles, particulates, or suspended particulate matter (SPM). At the most basic level, particulate matter is a collective term that encompasses a mixture of many fine solid and liquid particles, suspended in the earth's atmosphere. These particles may include dust, fly ash, soot, smoke, aerosols, fumes, mists and condensing vapours that can be suspended in the air for extended periods of time. In the last few years, particulate matter has received considerable media attention largely because of the increased number of deaths due to particulate related health diseases. Environmental degradation has also been attributed to airborne particulate matter, especially in developing countries where the concentration of these particulates are very high due to construction/industrial activities. The damage from these particulates in developing countries is estimated at billions of dollars. Particulate matter has also drawn significant attention from the scientific community because of its apparent role/contribution in cloud formation and climate change and is currently a subject of extensive research.

These sources include windblown dust and wildfires. Secondary PM sources directly emit air contaminants into the atmosphere that form or help form particulate matter. Hence, these pollutants are essentially considered precursors to PM formation. These secondary pollutants include SO_x, NO_x, VOCs, and ammonia. There are many different types of particulate matter, which may be distinguished into separate groups, based on their size; Total suspended particles, which include all particles of whatever size; PM₁₀ which are particles that are less than 10 μm (10 microns) in diameter; PM_{2.5} that are less than 2.5 μm in diameter. The most dangerous among the category

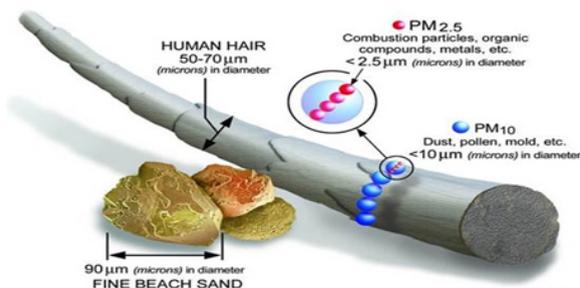
turbulent coagulation with water droplets. These deposition can induce great changes in the ecosystem. The next section discusses the various effects of particulate matter on plants, climate, human health and ecosystem in general.

I. CLIMATE EFFECTS

The change in the earth's climate is driven by certain perturbations in the earth's energy balance. These perturbations are collectively referred to as "climate forcing", and have been the subject of considerable research for predicting future change in the earth's climate. Variations in climate forcing are defined or determined by physical influences on the atmosphere such as orbital and axial changes as well as by the presence of certain agents such as greenhouse gases and aerosol particles, which are capable of altering the earth's energy balance. This in turn brings about changes in the earth's global temperature and thereby changes in the climate. The contribution of particulate matter in this change is very substantial. Particulate matter can affect the climate either directly i.e. through the process of scattering and absorption of the solar radiation, or indirectly i.e. through the formation of cloud condensation nuclei (CCN). The direct contribution of particulate matter is due to the presence of sulphate aerosols, fossil fuel soots and emissions from biomass burning in the earth's atmosphere.

Certain pollutants, among which elementary carbon appears to be the dominant factor apart from ozone, can induce rise in temperature through the process of heat absorption. For instance, black carbon, a particulate pollutant produced from combustion contributes to the warming of the earth. On the other hand, some components of particulate matter such as SO₂ cools the earth's atmosphere.

DEPOSITION PROCESSES



DEPOSITION PROCESSES

Particulate matter can collect or deposit themselves on solid surfaces, via two sub-processes: *dry* and *wet* deposition. The former includes deposition by impaction, interception, gravitational sedimentation, turbulence and other processes such as thermophoresis, electrophoresis etc while in the latter condition, atmospheric hydrometeors (rain drops, snow etc.) scavenge aerosol particles. This essentially means that wet deposition is gravitational, Brownian and/or

I. (a) Scattering and absorption of light due to aerosol particles

The scattering of light is a general physical process and is defined as the redistribution of light in non parallel directions when it interacts with small particles of matter. Light scattering of aerosol particles can happen due to the presence of a wide variety of aerosol types, among which the carbon and sulphate containing particles is believed to be the most efficient. Scattering due to aerosol mode particles (particles whose diameter are of the same order as the wavelength of the incident light) produces a negative forcing (cooling effect) as the scattered light from these particles falls predominantly into the region of Mie scattering which is characterised by up-scattered light that is reflected back into space (i.e. the scattered light does not reach the earth's surface).

I. (b) Formation of cloud condensation nuclei by aerosol particles

Many different types of aerosol particles can act as cloud condensation nuclei (CCN) around which the cloud droplets are formed. The relative ability of these different type of aerosol particles to produce cloud droplets differ according to their size and composition. The total number and the types of CCNs formed can directly influence the amount of precipitation, lifetime and the radiative properties of the cloud, and hence directly affect climate change.

II. EFFECT ON HUMAN HEALTH

Particulate matter is, at present, being extensively researched because of its visible and indisputable effect on human health, although it truly drew increased attention from scientists at the beginning of the 80s. Many scientific studies have since then been published that shows that a direct link can be established between exposure to particle pollution (both short term and prolonged exposure) and health risks, including premature death. Such studies indicate that fine particles are largely responsible for the observed health problems in humans and correlate exposure to fine particles to increased instances of asthma, decreased lung functioning ability in children, increased hospital admissions and increased mortality rates.

The heavy metal constituents of particulate matter is also a matter of important consideration. There are plenty of substantial evidences that shows that heavy metals adsorbed to atmospheric particulate matter is what confers toxicity to PM. These heavy metals have complex pollution features. Fine particles can contain heavy metals such as arsenic, cadmium, selenium etc. Many studies on these heavy metal constituents of PM have reported that exposure to high concentration of heavy metals can have adverse effects on the human health. In addition, these metals can get deposited to plant leaves, soil, water bodies etc via wet and dry deposition. These may then get collected in the plant's body through biochemical processes and humans may accumulate these metals through consumption of the contaminated plants. Table 2 discusses some heavy metals and their associated effects on human health.

POLLUTANT	SOURCE	EFFECT ON HUMAN HEALTH	MINIMUM PERMISSIBLE LEVEL
ARSENIC	Chemical pesticides, electronic wastes, smelting etc.	Inflammation of the respiratory organs; bronchitis, dermatitis, inflammation of liver, anaemia, cardiovascular diseases	0.0003 mg/kg/day of oral exposure
LEAD	Emissions from vehicles and industries, paint, mining, burning of plastic etc.	Irritation of the gastro-intestinal tract, kidney and liver damage	Less than 10 micrograms per decilitre of blood
ZINC	Oil and petroleum refineries, plumbing, metal plating etc.	Irritation of the eye, suppression of iron and copper absorption	0.002-0.005 mg/kg/day
MERCURY	Electronic wastes, dental and pharmaceuticals wastes etc.	Poor coordination, skin rashes, anxiety and memory problems, decreased intelligence	Less than 10 micrograms per decilitre of blood
CADMIUM	Pesticides, chemical fertilisers, welding, nuclear power plants etc.	Gastrointestinal damage, kidney damage, has carcinogenic properties	Less than 1 microgram per decilitre of blood

Table 2: Effects of heavy metal constituents of PM on human health

III. EFFECT ON PLANTS

When plants are exposed to a wide range of pollutant concentration, the pollutants may trigger various phytotoxic responses in plants, depending on the characteristic features of the particulate mixture that is being deposited. In general, plants are capable of filtering coarse particles at a much faster rate than fine particles. Particulate deposition on plants may consist of (i) nitrate and sulfate and (2) trace elements and heavy metals. The acid-forming sulfate and nitrate particles are comparatively more soluble and more reactive than mineral dusts. Particulate matter with pH values of ≥ 9 may prove toxic to the leaf tissues on which they are deposited. They can also adversely affect the

plants indirectly through modification of the soil pH.

Plants provide a massive leaf surface area for absorption and accumulation of dust particles. Dust deposited on the surface of the leaves can greatly modify the optical properties of photosynthetic tissues, and the amount of

light that is available for photosynthesis. This happens because the dust particles are finely arranged or concentrated on the leaf surface, thus effectively shading or shielding the leaves from photosynthetically active radiation (PAR).

IV. PARTICULATE STRESS ON ECOSYSTEM

Ecological responses to particulate stress varies widely. Succession in unpolluted environment is considered favourable while those places where particulate air pollution is high hinders the growth of organisms and plants. These particulates interferes with the normal physiology and biochemistry of the plants and animals and subsequently affects the food chain, nutrient cycling and energy flow. Furthermore, particulate matter from anthropogenic sources may affect the environment and the organisms so harshly that it becomes impossible for them to recuperate from the damage and propel them towards further degradation. Chronic pollutant injuries to a forest ecosystem may result in the permanent loss of susceptible species of plants, and even animals. Dust coating may prompt abrasion and radiative heating, and may greatly reduce the photosynthetically active radiation reaching the plant tissues.

CONCLUSION

It is clear that particulate matter has important and predictable effects on plants, climate, human health and the ecosystem. Industrialisation, population growth and associated increase in energy demands have resulted in a profound increase of these fine particles. The elevated levels of these particles in the earth's atmosphere can not only threaten the health of human beings, plants and animals but also adversely affect the ecosystem balance. Hence, there is utmost need to study, visualise and identify new strategies that can minimise the presence of these particles in the environment.

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