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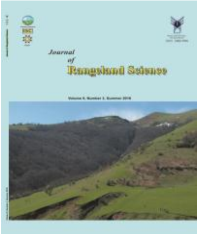

**Review and Full Length Article:**

# Dust Particles and Aerosols: Impact on Biota "A Review" (Part III)

Victor Roy Squires[A], Elahe Karami [B]

[A] Prof., Ecology and Resources Group, Gansu Agricultural University, Lanzhou, China (Corresponding Author), Email: dryland1812@internode.on.net
[B] M.Sc. Student, Department of Rangeland Management, Young Researchers Club, Boroujerd Branch, Islamic Azad University, Boroujerd, Iran

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**Abstract.** Natural resources play a fundamental role in the economy of country and create the situation to achieve the goals of sustainable society, these valuable resources have to be conserved and used with care. Destroying the forests and rangelands will lead to a dark future full of poverty, starvation and environmental pollution. Forests and rangelands play a considerable role in reducing air pollution, minimizing soil erosion, protect against destructive floods, creating a pleasant place of recreation and relaxation while also allowing recharge of underground water resources. In short, ensure the preservation of resources essential for life on the earth. This is Part 3 of a comprehensive review of the impact of dust particles and aerosols. Part 1 (Squires, 2016a) examined the mechanisms by which dust particles and aerosols become airborne and the effect of particle size on deposition patterns. Part 2 (Squires, 2016b) focussed on the impact of particulates on the physiology, and productivity of plants. In this paper, attention is directed to the impact on human health of dust and aerosols generated from dust storms and from industrial sites (mines, factories and from roadside dust generated by passing vehicles). Effects of such dust range from nuisance (that arises from loss of visibility) to increased costs of clean-up of premises, through to serious health problems generated by inhalation of dust particles and aerosols.

**Key words**: Particles and aerosols, Pollution, Rangeland, Forest, Health

## Introduction

Industrial emissions may occasionally result in excessive dust in nearby communities (Davies, 1974). Dust production has long been a critical human health issue for mining companies (Amponsah-Dacosta & Annegam. 1998). Dust may be harmful to health if poorly controlled. Mechanical and physical disturbance associated with mining activities, whether it is created by blasting and digging of soil and rock, transportation of materials or processing of ore, can create dust problems (Doley & Rossato, 2010). Dust is generated throughout the 'whole life of mine'. A lot of dust particles get suspended in the air and potentially affect the surroundings. Table 1 lists criteria for deposition along with predicted impacts at which these levels would typically occur around a source.

**Table 1.** Significance Criteria for Dust Deposition in relation to dust source and predicted impacts and the distances at which these levels would typically occur around a source.

| Annual Mean Deposition Rate mg/m$^2$/day | Effect | Distance From source | Significance |
|---|---|---|---|
| <350 | Nuisance and damage to plants unlikely | <200 m | Nonsignificant |
| 350-650 | Nuisance and damage possible | 100-200 m | Minor |
| 600-950 | Nuisance and damage probable | 50-100 m | Moderate |
| 950-1190 | Nuisance and damage highly probable | 20-50 m | Major |
| >1190 | Serious complaints and severe damage to plants and health | <20 m | Critical |

The type and size of a dust particle determines how toxic the dust is. However the possible harm the dust may cause to health is mostly determined by the amount of dust present in the air and length of the exposure. For people with respiratory conditions like asthma, chronic obstructive airways disease (COAD) or emphysema even small increases in dust concentration can make their symptoms worse.

Dust particles small enough to be inhaled (usually < 2.5μm) may cause:

- Irritation of the eyes
- Coughing
- Sneezing
- Hay fever
- Asthma attacks

Urban dust is measured as Atmospheric particulate matter (PM2.5μm). Total Suspended Particles (TSP) refers to the sum of PM2.5 and PM10 (that really encompasses particles up to 25 μm) and is commonly monitored and quoted as a measure of dust loading in the air. TSP is of concern because of loss of visibility at very high levels of dust can also impact on amenity having considerable nuisance value (air craft movements can be disrupted, schools closed and so on), as well as jeopardising some industries that require dust-free facilities (e.g. electronics) if dust levels are high. Table 2 shows the guidelines for protection of human health.

**Table 2.** Air quality Standards for the Protection of Health

| Pollutant | Averaging period | Air quality Standards (μg/m$^3$) Guidelines |
|---|---|---|
| PM10 | 24 hour mean | 50 |
| | Annual mean | 20 |
| PM2.5 | 24 hour mean | 25 |
| | Annual mean | 10 |

If dust is released into the atmosphere, there is a good chance that someone will be exposed to it and inhale it. If the dust is harmful, there is a chance that someone will suffer from an adverse health effect, which may range from some minor impairment to irreversible disease and even life-threatening conditions, including an implication in heart disease.

## How does dust affect human health?

Atmospheric particulate matter (PM) with aerodynamic diameter < 10 µm diameter (PM10) or < 2.5 µm diameter (PM 2.5) are of great concern for public health due to presence of polycyclic aromatic hydrocarbons (PAHs) (Liu *et al.,* 2013; Prajapati & Tripathi, 2008). Numerous epidemiologic studies highlighted the health implication of fine particles, with aerodynamic diameter smaller than 10 µm (Kampa & Castanas, 2008). Characterization of potential PM impacts on ecosystem function, remain important research needs with great potential significance for human welfare Prajapati and Tripathi, 2008; Telesca and Lovallo, 2011). The total suspended particulate matter (TSPM) in the atmosphere includes particles >10 µm diameter and these larger particles are important in the planning and management of mining, industrial and agricultural operations in order to protect human health (Mulligan, 1996).

## What happens when dust is inhaled?

When a person breathes in, particles suspended in the air enter the nose, but not all of them reach the lungs. The nose is an efficient filter. Most large particles are stopped in it, until they are removed mechanically by blowing the nose or sneezing. Particle size affects the region of the lung that is most susceptible (Fig. 1).

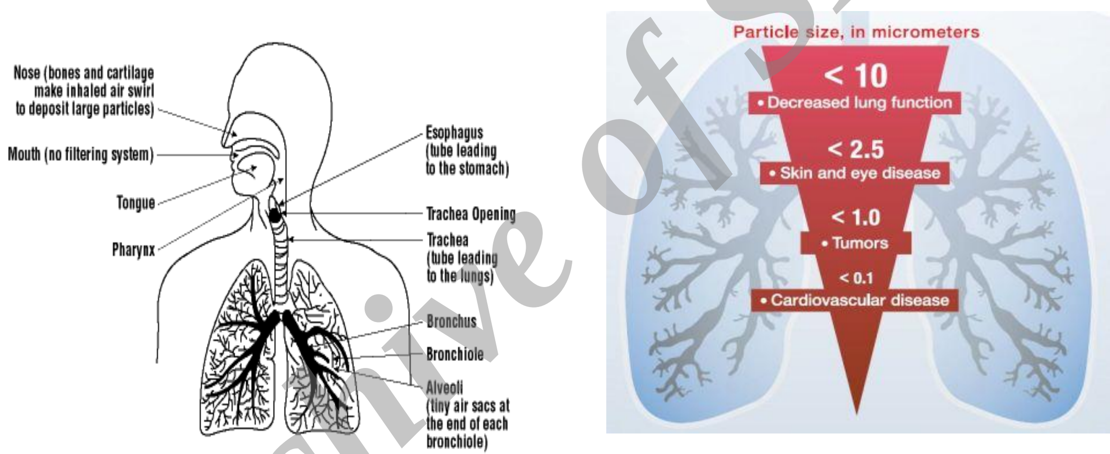


**Fig. 1.** Schematics of the lungs indicating the various regions of the respiratory tract and the vulnerability to harm from inhaling dust particles and aerosols

The health risk associated with dust depends on the type of dust (physical, chemical and mineralogical characteristics), which will determine its toxicological properties, and hence the resulting health effect; and the exposure, which determines the dose. Exposure depends on the air (usually mass) concentration and particle aerodynamic diameter of the dust in question, and exposure time (duration). The dose actually received is further influenced by conditions that affect the uptake, for example, breathing rate and volume. Particle aerodynamic diameters will determine if and for how long dusts remain airborne, their likelihood of being inhaled, and their site of deposition in the respiratory system. Dust concentration in the air and the aerodynamic diameter of the particles will determine the amount of material deposited, hence the dose received at the critical site (Squires, 2016a). Particles small enough to stay airborne may be inhaled through the nose (nasal route) or the mouth (oral route). The probability of inhalation depends on particle aerodynamic diameter, air movement round the body, and breathing rate. The inhaled particles may then either be deposited or exhaled again, depending on a whole range of physiological and particle-related factors. The five deposition mechanisms are sedimentation, inertial impaction, diffusion (significant only for very small particles < 0.5 µm), interception, and electrostatic deposition. Sedimentation and impaction are the most important mechanisms in relation to inhaled airborne dust, and these processes are governed by particle aerodynamic diameter. There are big differences between an individual's response to dust and in the amount deposited in different regions. The largest inhaled particles, with aerodynamic diameter greater than about 30 µm, are deposited in the airways of the head, that is the air passages between the point of entry at the lips or nares and the larynx. During nasal breathing, particles are deposited in the nose by filtration by the nasal hairs and impaction where the airflow changes direction. Retention after deposition is helped by mucus, which lines the nose. In most cases, the nasal route is a more efficient particle filter than the oral, especially at low and moderate flow rates. Thus, people who normally breathe part or all of the time through the mouth may be expected to have more particles reaching the lung and depositing there than those who breathe entirely through the nose. During exertion, the flow resistance of the nasal passages causes a shift to mouth breathing in almost all people. Other factors influencing the deposition and retention of particles include cigarette smoking and lung disease. Of the particles which fail to deposit in the head, the larger ones will deposit in the tracheobronchial airway region and may later be eliminated by mucociliary clearance or - if soluble - may enter the body by dissolution. The smaller particles may penetrate to the alveolar region deep inside (Fig. 1).

The lungs are constantly exposed to danger from the dusts we breathe. Luckily, the lungs have another function - they have defense mechanisms that protect them by removing dust particles from the respiratory system. For example, during a lifetime, a coal miner may inhale 1,000 g of dust into his lungs. When doctors examine the lungs of a miner after death, they find no more than 40 g of dust. Such a relatively small residue illustrates the importance of the lungs' defenses, and certainly suggests that they are quite effective. On the other hand, even though the lungs can clear themselves, excessive inhalation of dust may result in disease. Some of the smaller particles succeed in passing through the nose to reach the windpipe and the dividing air tubes that lead to the lungs. These tubes are called bronchi and bronchioles. All of these airways are lined by cells. The mucus they produce catches most of the dust particles. Tiny hairs called cilia, covering the walls of the air tubes, move the mucus upward and out into the throat, where it is either coughed up and spat out, or swallowed. The air reaches the tiny air sacs (alveoli) in the inner part of the lungs with any dust particles that avoided the defenses in the nose and airways. The air sacs are very important because through them, the body receives oxygen and releases carbon dioxide.

Dust that reaches the sacs and the lower part of the airways where there are no cilia is attacked by special cells called macrophages. These are extremely important for the defense of the lungs. They keep the air sacs clean. Macrophages virtually swallow the particles. Then the macrophages, in a way which is not well understood, reach the part of the airways that is covered by cilia. The wavelike motions of the cilia move the macrophages which contain dust to the throat, where they are spat out or swallowed. Besides macrophages, the lungs have another system for the removal of dust. The lungs can react to the presence of germ-bearing particles by producing certain proteins. These proteins attach to particles to neutralize them.

## What are the reactions of the lungs to dust?

The way the respiratory system responds to inhaled particles depends, to a great extent, on where the particle settles. For example, irritant dust that settles in the nose may lead to rhinitis, an inflammation of the mucous membrane. If the particle attacks the larger air passages, inflammation of the trachea (tracheitis) or the bronchi (bronchitis) may be seen. The most significant reactions of the lung occur in the deepest parts of this organ. Particles that evade elimination in the nose or throat tend to settle in the sacs or close to the end of the airways. But if the amount of dust is large, the macrophage system may fail. Dust particles and dust-containing macrophages collect in the lung tissues, causing injury to the lungs. The amount of dust and the kinds of particles involved influence how serious the lung injury will be. For example, after the macrophages swallow silica particles, they die and give off toxic substances. These substances cause fibrous or scar tissue to form. This tissue is the body's normal way of repairing itself. However, in the case of crystalline silica so much fibrous tissue and scarring form that lung function can be impaired. The general name for this condition for fibrous tissue formation and scarring is fibrosis. The particles which cause fibrosis or scarring are called fibrogenic. When fibrosis is caused by crystalline silica, the condition is called silicosis.

## What are the factors influencing the effects of dust?

Several factors influence the effects of inhaled particles. Among these are some properties of the particles themselves (Squires, 2016a). Particle size is usually the critical factor that determines where in the respiratory tract that particle may be deposited. Chemical composition is important because some substances, when in particle form, can destroy the cilia that the lungs use for the removal of particles. The fractions of the airborne particles inhaled and deposited in the various regions depend on many factors. However, for sampling purposes conventions have been agreed in terms of aerodynamic diameter, which say what should be collected, depending on which region is of interest for the substance and hazard concerned. Three broad groups are recognized: the *Inhalable particulate fraction* is that fraction of a dust cloud that can be breathed into the nose or mouth; the *Thoracic particulate fraction* is that fraction that can penetrate the head airways and enter the airways of the lung and the *Respirable particulate fraction* is that fraction of inhaled airborne particles that can penetrate beyond the terminal bronchioles into the gas-exchange region of the lungs. It should be noted that other dust characteristics besides composition and particle aerodynamic diameter can be important in dust control, for example, adhesion, light scattering, absorption capacity, solubility and hygro-scopicity. For better understanding of these issues, the reader may consult Chapters 1, 5 and 6 in Vincent (1995).

Cigarette smoking may alter the ability of the lungs to clear themselves. Characteristics of the person inhaling particles can also influence the effects of dust. Breathing rates and smoking are among the most important. The settling of dust in the lungs increases with the length of time the breath is held and how deeply the breath is taken. Whether breathing is through the nose or mouth is also important. Wherever the particles are deposited, either in the head or in the lung, they have the potential to cause harm either locally or subsequently elsewhere in the body. Particles that remain for a long time have increased potential to cause disease. This is why inhaled particles are important in relation to environmental evaluation and control.

The classic diseases of "dusty" occupations may be on the decline, but they have not yet disappeared. Workers today still suffer from a variety of illnesses caused by dust they inhale in their work environments. For practical purposes, I limit this document specifically to dust. I do not take into consideration combined effects arising from exposures to dusts, gases, fumes and vapours. The changes which occur in the lungs vary with the different types of dust. For example, the injury caused by exposure to silica is marked by islands of scar tissue surrounded by normal lung tissue. Because the injured areas are separated from each other by normal tissue, the lungs do not completely lose their elasticity. In contrast, the scar tissue produced following exposure to asbestos, beryllium and cobalt completely covers the surfaces of the deep airways. The lungs become stiff and lose their elasticity. Not all inhaled particles produce scar tissue. Dusts such as carbon and iron remain within macrophages until they die normally. The released particles are then taken in again by other macrophages. If the amount of dust overwhelms the macrophages, dust particles coat the inner walls of the airways without causing scarring, but only producing mild damage, or maybe none at all. Some particles dissolve in the bloodstream. The blood then carries the substance around the body where it may affect the brain, kidneys and other organs. Some types of lung diseases caused by the inhalation of dust are called by the general term "pneumoconiosis." This simply means "dusty lung." Table 3 shows some specific lung diseases that are commonly associated with certain workplaces.

**Table 3.** Summary of some of the most common lung diseases caused by dust

| Some types of pneumoconiosis according to dust and lung reaction | | |
|---|---|---|
| **Dust** | **Type of Disease** | **Lung Reaction** |
| **Inorganic Dust** | | |
| Asbestos | Asbestosis | Fibrosis |
| Silica (Quartz) | Silicosis | Fibrosis |
| Coal | Coal Pneumoconiosis | Fibrosis |
| Beryllium | Beryllium Disease | Fibrosis |
| Tungsten Carbide | Hard Metal Disease | Fibrosis |
| Iron | Siderosis | No Fibrosis |
| Tin | Stannosis | No Fibrosis |
| Barium | Baritosis | No Fibrosis |
| **Organic Dust** | | |
| Moldy hay, straw and grain | Farmer's lung | Fibrosis |
| Droppings and feathers | Bird fancier's lung | Fibrosis |
| Moldy sugar cane | Bagassosis | Fibrosis |
| Compost dust | Mushroom worker's lung | No Fibrosis |
| Dust or mist | Humidifier fever | No Fibrosis |
| Dust of heat-treated sludge | Sewage sludge disease | No Fibrosis |
| Mold dust | Cheese washers' lung | No Fibrosis |

Publications on the interactions with human health (apart from lung diseases) are also being documented at a higher frequency (see References and Further Reading). The impact of roadside dust from vehicles has received much attention in recent years (Doley & Rossato, 2010; Freer-Smith *et al.*, 2005). Brake linings and other mechanical parts are also a source of worrying particulate matter. Diesel and other petroleum-based fuels give rise to dangerous emissions (Mulawa *et al.*, 1997). Air quality has become a major concern. WHO (1987) set some guidelines as shown in Box 1. Dust is also of concern because of the potential for dust deposition to adversely affect amenity, for example by causing closure of airports, schools and the damage caused to factories that require a dust-free workplace e.g. electronic factories and the increased cleaning costs for removing dust from windows and other surfaces.

**Box 1 Airborne Pollutants**

The criteria for evaluation of changes in air quality with respect to impacts of airborne pollutants on health are derived from WHO (1987) Guidelines. They state that:
Projects with significant sources of air emissions, and potential for significant impacts to ambient air quality, should prevent or minimise impacts by ensuring that:
* emissions do not result in pollutant concentrations that reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines, or other internationally recognized sources; and
*emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards. As a general rule, the Guideline suggests using 25 percent of the applicable air quality standards to allow additional, future sustainable development in the same airshed [i.e. in an undegraded airshed]

## Conclusion

This Review (Parts 1, 2 and 3) highlights the many ways (Fig. 1) in which aeolian processes play a major role in the biosphere, including the role of soil in the absorption of air pollutants (Buba, 2013). There is a growing interest in the scientific community to understand and to model these processes, as indicated by the increasing number of publications, especially reviews on various aspects of dust on plants in the past few decades (Doley & Rossato, 2010; Mahowald *et al.*, 2014).

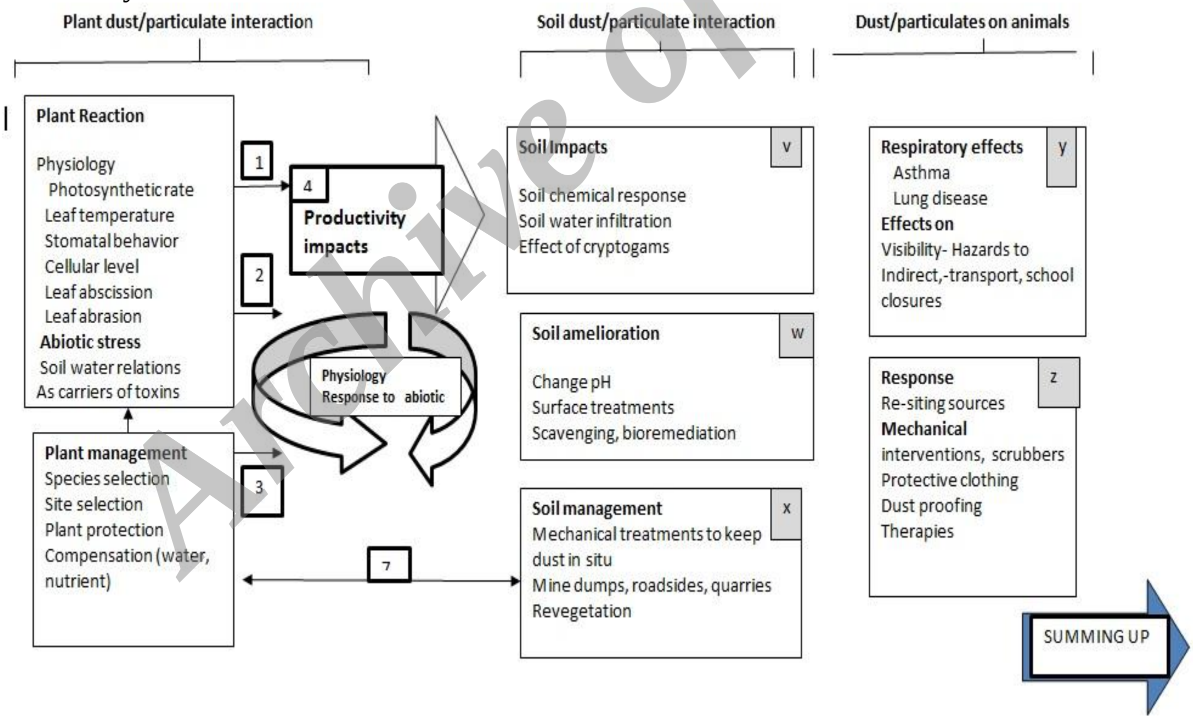


**Fig. 2.** The role of wind erosion in the biosphere

CAPTION Fig. 2 Framework for thinking about impact of dust and particulate matter on biota. The detrimental effects of dust and other airborne particulates is a function of physics, mineralogy, chemistry and their interaction with the physiology and response of the impacted biota and abiotic mileu in which the interaction occurs. Feedback loops between organism and the impacting particulates regulate important physiological reactions including photosynthetic rates in plants, stomatal behavior, leaf temperature and the creation of surface conditions conducive to colonization by other organisms. Dust particulates may also be vehicle to transport fungi and bacteria to leaves. Some of these may be pathogens. Plants roots are also affected directly and indirectly. But plants are not the only organisms affected. Invertebrates, whose life cycles depend on plants, are also adversely affected by dust accumulations and more subtly by shifts in community structure as the cumulative effects of dust loads bring about shifts in community structure and botanical composition. Vertebrates including humans are damaged by dust and wind-borne particulates. The Fig. 2 and the Review focuses on the impact of dust and particulates and the numbered circles indicate the different section numbers of the review.

What are some the key insights to take away from this review (Parts 1, 2 and 3). Regarding impacts of dust particles and dust aerosols, impacts on plants, soils invertebrates and other biota, including humans, there are five key conclusions and take home lessons. *First*, dust emissions arise from various sources and this has a major influence on the impacts on biota. The chemistry of particles and aerosols from sources has direct implications for biogeochemical cycles related to aerosol impacts and source deposition patterns and impacts (Squires, 2016a). *Second*, there are important interactions between dust and ecosystems stemming from the effects of dust through direct physical damage to plants (abrasion) but also there is interference with light absorption and photosynthesis that affects productivity (Squires, 2016b). *Third*, aeolian effects on agriculture from reductions in soil cover and from altering the soil surface and are due to either changes in the soil resource, through soil loss or redistribution, and entrained dust particles and aerosols is also of concern because of the potential for dust deposition to adversely affect amenity. For example by causing closure of airports, schools and the damage caused to factories that require a dust-free workplace e.g. electronics factories and the increased cleaning costs for removing dust from windows and other surfaces. *Fourth*, dust emissions directly affect human health via risk from dust inhalation associated with pathogenic microorganisms, toxic chemicals, and radionuclides (Telesca and Lovallo, 2011). Disturbances to the land surface that increase these types of dust emissions also increase risks to human health (Prajapati & Tripathi, 2008; Kampa & Castanas, 2008). *Fifth*, the interactions between roadside dust (especially re-suspension (Lin *et al.*, 2005) and vehicular aerosol emissions has received a lot attention (Chaston & Doley, 2006; Doley & Rossato, 2010) as well as the role of trees and shrubs as collectors of air borne particles and as “lungs” for urban areas (Liu *et al*., 2013).

While the physiological effects on plants (ranging from lichens to forests) have been studied by many (Part 2 ,Squires, 2016b) it is uncertain whether the physical effects of dust on plant physiology are permanent, because plants seems to recover after rainfall, which may wash dust off leaf surfaces and thus restore photosynthetic capacity. It should be possible to estimate dust thresholds which define the amount of acceptable dust loading on plants and other biota (Holmes & Marawska, 2006; Doley & Rossato, 2010). This should help to determine environmentally sustainable dust levels for protection of biota –including humans.

## Acknowledgements

Any broad review of this type owes a lot to the myriad of researchers’ world wide whose efforts have brought us to the present state of knowledge. I have drawn heavily on the work of all of them and my gratitude to this ‘invisible college” is immense.

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# تاثیر ریزگردها و ذرات معلق در هوا بر روی موجودات زنده (بخش سوم)

ویکتور روی اسکورز[الف] ، الهه کرمی [ب]

[الف]گروه منابع و اکولوژی دانشگاه کشاورزی گانژو، استان لانژو، چین (نگارنده مسئول)، پست الکترونیک: dryland1812@internode.on.net
[ب] کارشناسی ارشد مهندسی مرتعداری، دانشگاه آزاد اسلامی، واحد بروجرد، باشگاه پژوهشگران جوان، بروجرد، ایران

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**چکیده.** منابع طبیعی، نقش زیربنایی برای اقتصاد کشور دارد و زمینه‌ساز حرکت در جهت دستیابی به اهداف توسعه پایدار است. اگر خواسته شود که در آینده جامعه پایداری وجود داشته باشد، بایستی در جهت احیا و توسعه این منابع ارزشمند بیش از پیش کوشش شود. نابودی جنگل‌ها و مراتع، تصویری تاریک توأم با فقر، گرسنگی و آلودگی‌های زیست محیطی را از آینده ترسیم می‌کند. جنگلها و مراتع در کاهش آلودگی هوا، جلوگیری از فرسایش خاک، بروز سیلاب‌های مخرب، ایجاد محیطی دلپذیر برای تفریح و آسایش و همچنین تغذیه سفره‌های آب زیرزمینی نقش بسیار مهمی دارند و ضرورت وجود این منابع را برای ادامه حیات در هر نقطه از این کره خاکی مشخص است. بخش سوم این مقاله شامل بررسی جامع تاثیر ریزگردها و سایر ذرات معلق در هوا بر روی موجودات زنده است. در بخش اول مکانیسم هایی موثر در انتقال ریزگردها و ذرات معلق در هوا و تاثیر اندازه‌ی ذرات را بر روی الگوی انتقال و جابجایی ریزگردها بحث شد. نیز در بخش دوم تاثیر ریزگردها بر روی فیزیولوژی و بهره‌وری گیاهان قبلا توسط نگارنده بررسی شد. در این مقاله، به تاثیر ریزگردهای ایجاد شده از طوفان‌های گرد و خاک و اماکن صنعتی مانند معادن، کارخانه‌ها و جاده‌ها بر روی سلامت انسان و سایر موجودات زنده توجه شده است. تاثیرات چنین ریزگردهایی از جنبه کاهش دید و هزینه‌های گزاف پاکسازی محیط و مشکلات جسمی جدی ایجاد شده توسط این ذرات در این مقاله بررسی می‌شود.

**کلمات کلیدی:** ریزگردها، آلودگی هوا، مراتع، جنگل، سلامتی