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SOURCES FORMATION TRANSPORT DEPOSITION HEALTH AND ENVIRONMENTAL EFFECTS AND CONTROL TECHNOLOGY OF RESPIRABLE PARTICLES (PM2.5)

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Abstract. *Size of particle is the pivotal determinant of the properties of particles and it has implications on formation, physical and chemical properties, transformation, transport, and removal of particles from the atmosphere and effects on humans and the environment. The most insidious particle size to humans and the environment is the Respirable particles (PM2.5). Respirable suspended particles (RSP) are particles whose diameter are 2.5 micrometres or less. The major route of these particles to the human body is through inhalation. These particles are usually formed by the reaction of chemicals in the atmosphere and some of these chemicals are sulphur dioxides and nitrogen oxides that are emitted from power plants, industry and automobiles. These particulate matter are the deadliest form of air pollutants due to their ability to penetrate deep into the lungs and bloodstream unfiltered, causing permanent DNA mutations, heart attack and premature death. The residence time of respirable particles in the air is usually high as a result of their lightness and low density.*

Key words: *PM2.5, Transport, Source, Formation, Particles, Deposition and Impact*

1. INTRODUCTION

Respirable particle (PM2.5) is a microscopic solid or liquid matter suspended in the earth's atmosphere.

It is also known as particle pollutant, and is a complex mixture of extremely small particles and liquid droplets. Respirable particle (PM2.5) is made up of a number of components including acids such as nitrate and sulphate, organic chemicals, metals and soil or dust particles. The size of particles is directly linked to their potential for causing health problems. Environmental Pollution Agencies (EPAs) are concerned about particles that are very minute because these are the particles that generally pass through the nose and throat and enter the lungs. Once inhaled, these particles can affect the heart and lungs

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and cause serious health effects (Cohen et al.,2005; Ediagbonya et al.,2014a; Ediagbonya et al., 2015a; Ediagbonya et al.,2015b). Sources of Respirable particle (PM2.5) can be man-made or natural. They have impacts on climate and precipitation that adversely affect human health (Respirable particles (PM2.5) have a diameter of 2.5μm or less such as those found in smoke and haze. These particles can be directly emitted from sources such as forest fires or they can form when gases emitted from power plants, industries and automobiles react in the air. Respirable particle (PM2.5) behaves like a gas, that is they penetrate indoors from outside air and penetrate deep into lungs. Respirable particles (PM2.5) have greater aggregate surface area. They also adsorb toxic combustion products, metals and atmospheric air toxins, and carry them deep into the lungs (Ediagbonya et al.,2013; Gehring and Buchman,2003).

The IARC and WHO designate minute airborne particulates such as PM2.5 a Group I carcinogen. Particulates are the deadliest form of air pollutants due to their ability to penetrate deep into the lungs and bloodstream unfiltered, causing permanent DNA mutation, heart attack and pre-mature death.

2. Sources of Respirable Particles (PM2.5)

PM2.5 is a notorious pollutant with many sources contributing to the air quality problem. There are numerous sources of PM2.5, ranging from household furnaces to petroleum refineries.

Respirable particles (PM2.5) occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation and sea spray. Human activities such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of PM2.5 (Tiitia et al.,2002; Giugliano et al.,2005; Omid varborna et al.,2015). However, the major sources of PM2.5 can be grouped into two sources, namely:

1. Outdoor and indoor sources
2. Fossil fuel combustion and Biomass combustion.

1. Outdoor and Indoor sources: Outdoors, Respirable particles (PM2.5) primarily come from cars, trucks, buses and off-road vehicles (e.g. construction equipment, snow mobiles and locomotive) exhausts, other operations that involve the burning of fuels such as wood, heating oil or coal, and natural sources such as forest and grass fires. Respirable particles also form from the reaction of gases or droplets in the atmosphere from sources such as power plants. These chemical reactions can occur miles from the origin of the emission. Because Respirable particle can be carried long distances from their source, events such as wildfires or volcanic eruptions can raise Respirable particle (PM2.5) concentration hundreds of miles from the event. Some indoor sources of Respirable particles (PM2.5) are tobacco smoke, cooking (e.g. frying, sautéing and broiling), burning candles or oil lamps, and operating fire place and fuel-burning space heaters (e.g. kerosene heaters).

2. Fossil fuel combustion and biomass combustion: the fossil fuel combustion includes gasoline and diesel motor vehicles, coal-fired power generator and home heating oil. The biomass combustion includes residential fireplaces, wood stoves, forest fires (wild and controlled burns), and open burning. Respirable particles (PM2.5) are largely formed from gases. Combustion of fossil fuels such as coal, oil and petrol can produce Respirable particles (PM2.5) from the condensation of materials vaporized during combustion. Respirable particles (PM2.5) in the air are either directly emitted or transported, for instance when fuel is burnt and when dust is entrained by wind or indirectly transported, when gaseous pollutants previously emitted into the air turn into minute particles. Ediagbonya et al., (2014b).

3. FORMATION OF RESPIRABLE PARTICLE (PM2.5)

There are two major processes of particle formation in the atmosphere and they are mechanical process and chemical process. Minute particles such as Respirable particles (PM2.5) are usually formed in the atmosphere by chemical process Perrand et al., (2012).

The chemical process of Respirable particles can be from sources that burn fuel and emit gases. Here, the pollutant vaporises and then condenses to become a particle of the same chemical compound. The small particles can further react or combine with other compounds in the atmosphere. A major source of particles formed this way are the burning of fossil fuels in industry, transportation, agriculture etc. There is strong correlation between the formation of Respirable particles (PM2.5) in the atmosphere and temperature. This is because temperature can affect the formation of particles; thus, the high temperature can promote the photochemical reaction between precursors. Memmesheimer et al., (2004). The chemistry and physics of PM2.5 formations in the atmosphere is still unclear and hazy. During combustion processes Respirable particle (PM2.5) is released directly to the atmosphere as form of sulphur dioxide (SO2) and nitrogen oxides (NO_x) which are currently mirrored as the most important precursors. Ammonia and volatile organic compounds (VOCs), can also contribute to ambient Respirable particle (PM2.5). Direct Respirable particles (PM2.5) emissions may be largely responsible for one area's non-attainment, while SO_2 emission may cause the problem elsewhere. They can also be produced by condensation of gases that have been converted in atmospheric reactions to low-vapour pressure substances. For example, sulphur dioxide is oxidised in the atmosphere to form sulphuric acid (H_2SO_4), which can be neutralised by NH_3 to form ammonium sulphate.

Nitrogen dioxde (NO_2) is oxidised to nitric acid (HNO_3), which in turn can react with ammonia (NH_3) to form ammonium nitrate (NH_4NO_3). The particle produced by the intermediate reactions of gases in the atmosphere are called secondary particles. Secondary sulphate and nitrate particles are usually the dominant component of the respirable particle (PM2.5). Quinn and Batis, (2005).

4. TRANSPORT OF RESPIRABLE PARTICLE (PM2.5)

Respirable particle (PM2.5) does not always stay where it was made. In a stupefying short time, it can make its way around the globe. This process is called transport and dispersion and is very complex. There are three major factors that influence the way particles spread, including wind speed, relative humidity, and temperature. The effect of wind speed on Respirable particles (PM2.5) is twofold: one effect is that wind speed will determine the travel time of particles from sources to receptor. The other effect is the amount of pollutant dilute in the wind ward direction. The lightness and size of Respirable particles (PM2.5) have positive correlation with wind speed, the higher the wind the more the particles are transported to a larger area. When the wind speed is low, the entrainment of the particles by wind is reduced. The reduction of wind wind speed can lead to the accumulation of Respirable particles(PM2.5) in the area in which the particles are formed. The fate and transport of particles in the atmosphere depend in part on their size. Respirable particles (PM2.5) have a very long residence time- in the order of minutes to days- because they are likely to undergo gas-to-particle conversions. Temperature inversion has a correlation with the transport of minute particles in the atmosphere, when the temperature is favourable, there is formation and transportation particles either horizontally or vertically.

Humidity is the amount of water vapor in the atmosphere. Particulate matter is hygroscopic in nature. As the relative humidity increases Respirable particles(PM2.5) decrease. Therefore, the higher the relative humidity, the smaller the particulate in the atmosphere, the adsorption of water vapour onto the particulate matter may increase their settling rates and deposition (Ediagbonya et al.,2013; Quinn and Batis, 2005).

5. Deposition Processes of Respirable Particle (PM2.5)

Deposition involves the process of scavenging minute particles in the atmosphere. The most important characteristics influencing the deposition of particles are size and aerodynamic properties (Seinfied and Spyros, 1998).

There are two major types of deposition of atmospheric particles and they are wet deposition and dry deposition. The wet deposition is also known as the rainout or washout while dry deposition involves gravitational settling, impaction, condensation sedimentation and diffusion. Deposition by gravitational settling occurs as a result of the influence of gravity on particles suspended in the air. The settling rate of particles is directly proportional to the particle size. Impaction, which is another mechanism of particle deposition, it occurs when a minute or very small particles in the atmosphere collide or impact on the wall of another smaller particle to form a larger particle. The small particles are removed by impaction with surface cover and aggregation to form larger particle which are removed by settling or washout. In condensation process, lighter particles change to heavy particles. While sedimentation involves the process in which heavier particles fall from higher atmosphere to a lower atmosphere. Brownian diffusion involves collision between gas molecules and micrometer-sized particles, which push the particle in an irregular manner. It depends on the diffusive or thermodynamic diameter of the airborne particle rather than on the aerodynamic diameter. Due to this, Brownian diffusion increases with decreasing particle size. Respirable particles (PM2.5) are not easily deposited by dry deposition process (Ediagbonya et al.,2014b; Seinfied and Spyros,1998).

The most effective scavenger of Respirable particle (PM2.5) in the atmosphere is precipitation Ediagbonya et al., (2014b). The smaller particles may be accumulated in rain drops. This process is termed rain out rather washout. It has been reported that air pollutions may alter precipitation forming processes. Scavenging efficiency decreases with particle size and become negligible for particles 1μ and smaller. The small particles are removed by impaction with surface cover and aggregation to form larger particle which are removed by settling or washout.

6. Health Effect of Respirable Particles (PM2.5)

The size of particles is directly linked to their potential for engendering health problems. Respirable particles (PM2.5) have been fingered as one of the most notorious particle in the atmosphere. When one takes in air, he or she breathes in air along with any particles in the air. These particles (PM2.5) travel into human's respiratory system and stick to the sides of the airway or travel deeper into to lungs. It penetrates faster when the mucous lining in the lung had been damaged.PM2.5 can get down into the deepest (alveolar) portions of the lungs when gas exchange occurs between air and the blood

stream. These are the most dangerous and insidious particles in the atmosphere because the alveolar portion of the lungs has no potential means of exuding the particle especially when the particles are soluble in water, they can migrate into the blood stream within some seconds. When these particles are not soluble in water, with the help of the mucous lining they can be expectorated. However, PM2.5 has the potential to go deeply into the lungs and become trapped. This can result in lung disease, emphysema and lung cancer in so cases.PM2.5 can leave the lung and travel through the blood to other organs, including the heart. The main effects associated with exposure to respirable particle (PM2.5) may include premature mortality, aggravation of respiratory and cardiovascular disease; increased hospital admissions and emergency room visits, school absences, loss of work days, exacerbated asthma, acute respiratory symptoms, chronic bronchitis, decreased lung function and reduction in life expectancy.PM2.5 has also been fingered to exacerbate coronary artery disease, congestive heart failure and asthma. Plethora studies have fingered PM2.5 as a notorious cause of respirational illness varying from cardiovascular and respiratory health endpoints. Recent studies have implicated PM2.5 with cardiopulmonary mortality, hospitalization and emergency department visits and respiratory symptoms. Recent study indicated that PM2.5 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 problem. Exposure to Respirable particles (PM2.5) can cause short term health effects such as: Eye, nose, throat and lung irritation, coughing, sneezing, running nose and shortness of breath. However, children and the elderly, as well as people with pre-existing cardiovascular or respiratory diseases such as asthma, are particularly susceptible to health effects caused by PM2.5. (Ole Raachou et al.,2013; Pope and Dockery, 2006; Schwartz and Meas, 2000; Tobin et al.,2016)

7. Effect of Respirable Particles (PM2.5) on Environment

PM2.5 has effect on living material and non-living material one of the major cause of visibility impairment in the world is PM2.5. The particles in the air reduce the distance at which one can see the colour, and distant object because those particles scatter and absorb light. In many parts of the world pollution has reduced visual range by 70 percent from natural conditions. In addition to affecting visibility, PM2.5 particles can also lead to ecosystem damages. When there is cumulative deposition of nitrates and sulphates exerted the natural buffering or storage capacity of the ecosystem and affects the nutrient status of the ecosystem, usually by indirectly changing soil chemistry, populations of bacterial involved in nutrient cycling and or population of fungi involved in plant nutrient uptake (IPCC,2001; Lohonunn and Feichter, 2001; Ostron and Noone,2000; Seinfield and Spyros, 1998).

8. Control Technologies of Respirable Particle (PM2.5)

Particulate matter emissions are highly regulated in most industrialized countries. Due to environmental concerns, most industries are required to operate some kind of dust collection system to control particulate emissions. Dry dust collection, (2016). These systems include:

1. Inertial collectors (Cyclonic separators)
2. Wet scrubbers
3. Fabric filters collectors (bag houses)
4. Electrostatic precipitation

1. Cyclonic separators are useful for removing large, coarse particles and are often employed as a first stop or "pre-cleaner" to other more efficient collectors. Well-designed cyclonic separators can be very efficient in removing even fire particulates and may be operated continuously without requiring frequent shutdowns for maintenance. Region 4, (2008).

2. Fabric filters collectors (bag houses): are the most commonly employed in general industry. They work by forcing dust laden air through a bag shaped fabric filter leaving the particulate to collect on the outer surface of the bag and allowing the clean air to pass through to either being exhausted into the atmosphere or in some cases recirculated into the facility. Common fabrics include polyester and fiberglass and common fabric coating include PTFE (common known as Teflon). The excess dust builds up is then cleaned from the bags and removed from the collector. (Dominick Dal santo, (2010)

3. Wet scrubbers: This is when dirty air pass through a scrubbing solution (usually a mixture of water and other compounds) allowing the particulate to attach to the liquid molecules.

4. Electrostatic precipitators: electrically charge the dirty air as it passes through. The now charged air then passes by large electrostatic plates which attract the charged particle in the air stream collecting them and leaving the clean air to be exhausted or recirculated.

The control technologies for PM2.5 include:

1. Stationary source measures
2. On-road mobile source measures.
3. Non-road mobile source measures.
4. Supplemental appendix on on-road ammonia and VOC measures: In the notice of proposed rulemaking for PM2.5 implementations, EPA proposed to make a legal presumption that VOC and ammonia would not be regulated precursors for purposes of non-attainment areas of PM2.5 plan, unless the state or EPA makes a determination to the contrary.
5. Fugitive dust measures:
6. Improved source monitoring: for many of the stationary source measures
7. Control measures for agricultural sources such as diesel engine retrofits and other measure that can help reduce emissions of PM2.5 and precursors. Dry dust collection (2016)

9. CONCLUSION

The study of Respirable particle is becoming increasingly a burning issue in the world because of its notoriety. The major source of Respirable particle (PM2.5) is combustion and it is formed in the atmosphere by chemical process. The most effective way of removing respirable particle (PM2.5) is precipitation. Studies of Respirable particles (PM2.5) have been linked with a number of significant health effects. These include increased mortality and aggravation of existing respiratory and cardiovascular disease, as

evidenced by increased hospitalization, school absences and lost work days. Also the effect of Respirable particles (PM2.5) on living and non-living materials cannot be over-emphasised. It has corroding tendency, it can scatter light and above all, it is hygroscopic in nature.

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UTICAJ IZVORA ZAGAĐIVANJA IZ TRANSPORTA NA ZDRAVLJE LJUDI I ŽIVOTNU SREDINU I TEHNOLOGIJA ZA KONTROLU ČESTIČNIH MATERIJA (PM2.5)

Veličina čestice je najznačajnije svojstvo čestice koje utiče na formiranje, fizička i hemijska svojstva, transformaciju, transport, uklanjanje čestica iz atmosfere. na ljude i životnu sredinu. Najnepogodinije veličine čestica, sa najnegativnijim uticajem na ljude i životnu sredinu su udisajne suspendovanih čestice (PM2.5). Udisajne suspendovane čestice (RSP) su čestice čiji prečnik je oko 2,5 mikrometara ili manji. Čovek ove čestice disajnim putevima unosi u organizam. Ove čestice se obično formiraju reakcijom hemikalija u atmosferi, neke od ovih hemikalija su sumporna dioksid i oksidi azota koji se emituju iz elektrana, industrije i automobila. Ove čestice su najsmrtonosniji oblik zagađenja vazduha zbog njihove sposobnosti da duboko prodru u pluća i krvotok nefiltrirane, pri čemu izazivaju mutaciju DNK, obolenja srca a često i smrt. Vreme zadržavanja čestica u vazduhu je obično veliko što je rezultat njihove male težine i gustine.

Ključne reči: *PM2.5, transport, izvori, formacija, čestice, taloženje i uticaji*