Impact of Soot on the Environment, Livestock and the Well Being of Inhabitants of the Niger Delta Region, Nigeria

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ABSTRACT

This study was carried out to review the impact of soot on the environment, livestock and the well being of inhabitants of the Niger Delta Region, Nigeria. The study revealed that the environmental hazards caused by soot have become so alarming with the increase in artisanal refining of crude oil in the Niger Delta region of Nigeria. According to sources, the first observation of a high concentration of soot in parts of Port Harcourt was in November 2016. The soot first appears as clouds laden with dark particulate matter on the skyline in various parts of the state. The black soot accumulates in homes and makes everywhere appear dirty, even when cleaned thoroughly and regularly. It is visible on window nets, streets, walls, floors, and bedsheets, both private and public places, even on children's feet, innocently playing. Residents frequently wake up to toxic hydrocarbon emissions from nearby creeks and waterways that remain in the air for hours. A visitor could easily conclude that heavy rain was on the way. Still, for the residents who have grown accustomed to the situation, it's a sobering reminder of an environmental problem that refuses to go away. From this review, it is observed that soot pollution has contributed significantly to the unavailability of safe drinking water—76–80 percent in rural areas and 50–55 percent in urban areas lack access to safe drinking water. This supports the April 2018 ranking of Port Harcourt as one of the most polluted cities in the world, with an air index of 188. Similarly, Air Visual ranked Port Harcourt as "very unhealthy" for sensitive groups, having attained an air index of 207.817 in December 2020. Different impact of soot on temperature variability and the well being of inhabitants of Rivers State, Nigeria were identified that call for urgent attention.

Keywords: Soot, temperature, variability, Niger Delta, Nigeria.

INTRODUCTION

The need to review the impact of soot on the environment, livestock and the well being of inhabitants of the Niger Delta Region, Nigeria, cannot be overemphasized due to its impact on public health. Schmidt (2011) was of the opinion that contribution of soot to global warming is much higher than previously thought, according to a comprehensive assessment that ranks 'black carbon' second only to carbon dioxide in terms of its warming impact on the current climate. Black carbon's impact on the climate and the overall well being of humans is larger than that of methane and roughly two-thirds that of carbon dioxide, according to the study. Many toxicological and epidemiological studies established adverse health effects by particulate matter (DPM10, DPM2.5) indicate that exposure of diesel exhaust have been linked with acute short term problems such as irritation of the eyes, nose, and throat vomiting, light-headedness, headache, heartburn, numbness, bronchitis, chronic respiratory, cardiovascular, cardiopulmonary and allergic diseases such as shortness of breath and painful breathing, cancer, and premature death (Sydbom et al., 2001). Some investigations indicate that particles can induce inheritable mutations. Potential health impacts of DPM, ozone and carbon monoxide formed from diesel emissions on newborn children include birth defects, growth retardation and sudden infant death syndrome (Woodruff et al., 2008).

Diesel exhaust contains a variety of confirmed carcinogenic compounds such as formaldehyde, acetaldehyde, dioxins and polycyclic aromatic hydrocarbons (PAHs). Over 30 epidemiological studies link diesel exhaust to lung cancers (Hesterberg et al., 2012). Studies have also linked diesel exhaust to bladder cancer. On average, long-term occupational exposures to diesel exhaust were associated with an increase of ~ 40% in the relative risk of lung cancer. Population-based case -control studies identified statistically significant increases in lung cancer risk for truck drivers, rail, road workers and heavy equipment operators (Hesterberg et al., 2012).

EFFECT OF SOOT ON ANIMALS AND VEGETATIONS

Long term studies looking at the effect of diesel emission exposure in rats have demonstrated increased accumulation of particles and aggregates of particle laden macrophages in the alveoli and per bronchial interstitial tissues as well as local inflammation, epithelial proliferation, fibrosis and emphysematous lesions (Ishihara and Kagawa, 2003). Diesel emissions are associated with reproductive system impacts in animals. Pregnant rats exposed to diesel emissions resulted in elevated testosterone in the mother and reproductive organ changes such as masculinization of fetuses. Animal studies suggest diesel emissions may affect the immune system, including reduced immunity to bacterial infections in the lung (Watanabe and Kurita, 2001).

Particulate deposition and effects on vegetation unavoidably include (1) nitrate and sulphate and their associations in the form of acidic and acidifying deposition and (2) trace elements and heavy metals. Atmospheric diesel DPM impact agriculture productivity in a variety of ways: 1) reduction of solar radiation in turn reducing photosynthesis, 2) settling of soot particles on the plants can shield leaves from solar radiation hindering photsynthesis, 3) soot deposition can increase acidity and cause plant damage, and 4) reduction of rainfall by dimming induced by soot (Prasad and Bella, 2010).). It causes all type of injury in plants such as epinasty, nicrosis, chlorisis, abscission, flower dropping, etc (Prasad and Bella, 2010).)

EFFECT OF SOOT ON WATER AND SOIL POLLUTION

Atmospheric deposition of air pollutants released from diesel exhaust to ecosystems and their components, such as forests, water bodies, and soils, is another significant source of contamination (Ghorani-Azam et al., 2016). Water and soil are contaminated indirectly by dry and wet deposition of diesel exhaust emitted to the atmosphere. Wet deposition dominates the transfer of airborne contaminants to the Earth’s surface, but dry deposition may be important in arid areas where ambient concentrations are high and rainfall is limited. In urban areas, sedimentation of large particles is more important than wet deposition and dry gaseous and small particle deposition. Environmental effects of atmospheric deposition have been studied for a long time, but the mechanism is poorly understood. Enhanced levels of atmospherically deposited nitric and sulfuric acid (acid rain) adversely affect the health (Luo et al., 2019).

Xavier Mari et al (2014) worked on the effects of soot deposition on particle dynamics and microbial processes in marine surface waters. He observed that large amounts of soot are continuously deposited on the global ocean, the effects of these aerosols on ocean ecosystems are currently unknown. He used combination of in situ and experimental data, and results from an atmospheric transport model, shows that the deposition of soot particles from an oil-fired power plant impacted biogeochemical properties and the functioning of the pelagic ecosystem in tropical oligotrophic oceanic waters off New Caledonia. Deposition was followed by a major increase in the volume concentration of suspended particles, a change in the particle size spectra that resulted from a stimulation of aggregation processes, a 5% decrease in theconcentration of dissolved organic carbon (DOC), a decreases of 33 and 23% in viral and free bacterial abundances, respectively, and a factor ~2 increase in the activity of particle-attached bacteria suggesting that soot introduced in the system favored bacterial growth. These patterns were confirmed by experiments with natural seawater conducted with both soot aerosols collected in the study area and standard diesel soot. The data suggest a strong impact of soot deposition on ocean surface particles

EFFECT OF BLACK SOOT ON MAN, ENVIRONMENT AND SOCIAL ACTIVITIES

Pollution has been around for decades. It has silently crept in and negatively affected our daily lives. As pollution levels continue to rise, so does the potential for even more dangerous effects on our health and the environment. In the atmosphere, pollution occurs when particulate or gaseous contaminants are introduced in quantities that affect the environment negatively (Manisalidis et al., 2020). This condition is characterized by an increase in the oxidizing capacity of the atmosphere, reduced visibility in the atmosphere, and deterioration of the quality of the air in a region. As a result, it has a significant impact on the climate, the living environment, and the health of people (Akpinar, et, al., 2007). Black soot, also known as black carbon, is a by-product of incomplete combustion of fossil fuels, biofuels, and biomass. It is a major contributor to air pollution and has several negative effects on both human health, the environment, and social activities (Manisalidis et al., 2020). Black carbon (BC) originates from biomass and fossil fuels. It comprises a range of carbonaceous materials from char BC, the partially combusted solid residues of plant tissues, to highly graphitized soot BC, the volatile substances formed within flames (Schmidt et al., 2001). At their onset, soot or aerosol BC particles form as hydrophobic primary spherule aggregates with irregular geometry providing active sites for deposition of chemical species (Zhang et al., 2008; Crouzet et al., 1995). With decreasing particle size (particularly with sizes smaller than 2 mm), the ability of these particles to remain airborne in the atmosphere increases, promoting long distance transport (Suman et al., 1997). Immediately after fires, emitted BC particles larger than 1 µm may fail to become airborne or may otherwise quickly drop to the nearest surface (Masiello et al., 2004).

Furthermore, Black carbon (black soot) in the form of aerosols has received far less consideration, although it is a primary air pollutant produced by combustion activities and has a high global warming potential of 680 on a 100-year basis (Bond and Sun, 2005). When BC is buried and incorporated in the pedosphere, its long residence time and tendency to enhance other soil chemical and physical properties can increase the soil's potential to sequester carbon. Such burial is preceded by natural, anthropogenic or a mixture of both kinds of events such as wildfires, prescribed burns, biomass-based cooking and fossil fuel combustion. Subsequent ex-situ deposition of BC after aeolian or alluvial transport may occur (Bond and Sun, 2005). A primary component of soot is black carbon which absorbs light more than any other particle matter. For example, black carbon may absorb a million times more energy than the same mass's carbon dioxide (CO_2). Because of this energy absorption and interaction with clouds, black carbon is a significant source of concern for climate change. It's linked to rising temperatures, ice, and snow melting, especially in sensitive areas (U.S. EPA, 2012).

The impact of soot on the human health and to the entire environment depends on its distribution and its distance from the source of origin (Liu et al., 2011; Zhan et al., 2013). Soot from vehicle exhausts comes from combustion of diesel, gasoline, and other petroleum-based fuels materials that contains carbonaceous particles, having polycyclic aromatic hydrocarbons (PAHs) attached to it (Boffetta, 1997). Typically, diesel exhaust particles (DEP) are made up of carbon core with some volatile and semi-volatile (such as H2SO4 and organics) components adsorbed on it (Canagaratna et al., 2010; Alam et al., 2016). It has been believed that the vehicle exhaust contributes to approximately 50% of urban particulate matter (PM) (Cassee et al., 2013). The special attention is given to the smaller fractions of PM (PM 2.5 and PM 0.1) because these particles can penetrate deep into the bronchiolar parts of the lungs and cause various health hazards(Valavanidis et al., 2013). Furthermore, black soot has been shown to have a negative impact on human health in several ways. When inhaled, it can irritate the lungs and lead to respiratory problems, such

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as asthma, bronchitis, and lung cancer. Studies have also linked exposure to black soot to an increased risk of heart disease, as the particles can enter the bloodstream and cause inflammation and oxidative stress.

Inhaling black soot can also cause eye irritation and skin problems, and can harm the nervous system (Schwartz, 2009; Pope and Dockery, 2006). In addition, World Health organization (WHO) states that, air pollution constitutes the largest among all of the environmental risks: 3 million annual deaths are associated with outdoor air pollution exposure. In 2012 alone, 11.6 percent of global deaths equivalent to 6.5 million deaths were outdoor air pollution-related. 94% of the approximately 90% of air pollution-related deaths occurring in low and middle-income countries are as a result of non-communicable diseases, including cardiovascular diseases (CVDs), chronic obstructive pulmonary disease (COPD), and lung cancer. Industrial activities constitute a principal source of air pollution (WHO, 2017). Black soot can contribute to climate change by increasing the amount of heat-trapping greenhouse gases in the atmosphere. When deposited on snow and ice, it can darken the surface and reduce their ability to reflect sunlight, leading to melting and further contributions to global warming (Bond et al., 2013).

Environmentally, black soot affect climate change by absorbing and trapping heat in the atmosphere and reducing the amount of sunlight reflected back into space. It can also increase the melting of snow and ice, which can have cascading effects on the Earth’s climate system. When deposited on land, black soot can also alter soil fertility and nutrient content, leading to changes in vegetation patterns (Chylek et al., 2006). It has also been at the receiving end and overburdened with aftermath of the excesses of humans in their struggle for survival. Our Environment is a complex weave of physical, chemical and biotic factors that interact with each other and impact upon all living things and their surroundings. It is a life supporting system for human existence and survival as well as provides required for socio-economic progress (UNEP, 2011). The environment is the source of global economy that must be protected and managed sustainably, all efforts directed at managing and administering the environment is to ensure the continued existence of the biological diversity entities on the earth of which humans are the prime species and without it, which humans cannot exist (Aluko, 2005).

More so, Black soot can negatively impact outdoor activities, such as sports and recreation, by reducing visibility and making it more difficult for people to enjoy their surroundings. It can also have an adverse effect on tourism, as areas with high levels of air pollution are often considered less attractive to visitors (Kim and Kates, 2003; Pearce, 2002). Black soot can reduce crop yields by altering the nutrient content of soil and blocking photosynthesis. It can also harm the quality of crops by depositing on leaves and altering the content of essential nutrients and secondary metabolites. Studies have shown that exposure to black soot can increase the susceptibility of crops to diseases and pests, leading to further reductions in yields.

Black carbon (BC) has recently gotten a lot of attention from scientists and policymakers because of its effects on global and regional climate. Though significant and immediate reductions in long lived greenhouse gases (GHG) are required to solve the long-term problem of climate change, BC offers a promising mitigation opportunity to address climate effects in the short term and slow the rate of climate change (Cho, 2016). The high absorption capacity of BC and its role in key atmospheric processes link it to a variety of climate impacts, including increased temperatures, accelerated ice and snow melt, and disruptions in precipitation patterns (the United States Environmental Protection Agency, 2012).

According to Cho (2016), black carbon, a significant component of soot, is the most solar energy absorbing component of particulate matter, absorbing one million times more energy than CO_2 (carbon dioxide). The amount of energy stored in the atmosphere is measured in watts per square meter of the earth’s surface; according to a 2013 study, black carbon has an effect of 1.1 watts per square meter per year, second only to carbon dioxide, which has an impact of 1.56 square meter.

In other words, after CO2, black carbon is the second most significant contributor to climate change. However, unlike CO2, which can remain in the atmosphere for hundreds to thousands of years, black carbon, as a particle, only remains in the atmosphere for days to weeks before being washed back to earth by rain or snow (Levitsky, 2011). Since black carbon absorbs solar energy, it warms the atmosphere. When it falls to the ground as precipitation, it darkens the surface of snow and ice, lowering their albedo (the ability of a surface to reflect light), warming the snow, and hastening to melt. In addition to the impact of BC on atmospheric warming, Black carbon, like all particles in the atmosphere, influences cloud reflectivity, stability, duration, and precipitation. It has different effects depending on how much soot is in the air and where black carbon is in the atmosphere. It will evaporate if it absorbs heat at the level where clouds are forming. It has a cooling effect when it is located above lower stratocumulus clouds that block the sun. Scientists do not know how much black carbon directly contributes to global warming because it interacts with other components of particulate matter, such as sulfates and nitrates, which reflect sunlight and cool the atmosphere (Levitsky, 2011).

According to recent emissions inventories, Asia, Latin America, and Africa account for most global BC emissions. The patterns and trends of emissions vary greatly across regions, countries, and sources (United States Environmental Protection Agency, 2012). Arctic nations (including the EU's Denmark, Finland, and Sweden, as well as Canada, Iceland, Norway, Russia, and the United States) contribute about 10% of global human black carbon emissions (include wildfires, residential burning, the burning of agricultural and solid waste, maritime shipping, gas flaring and the combustion of diesel fuel), but their contribution to Arctic warming is thought to be greater because most black carbon particles do not travel far from their source (EU Service for Foreign Policy Instruments, 2019). Developing countries in Asia, Africa, and Latin America account for more than 75% of global black carbon emissions, primarily from cook stoves and the use of solid fuels such as coal and wood for heating, which has a particularly negative impact on the health of women and girls. Diesel vehicles and open biomass combustion, the world's largest source of black carbon, both contribute significantly to emissions (Cho, 2016).

The effects of black soot are far-reaching and can have a significant impact on human health, the environment, and social activities. It is important to reduce emissions from sources such as vehicles, power plants, and industrial processes, and to promote the use of clean energy sources to mitigate these negative impacts. The effects of black soot on human health, the environment, and social activities can result in significant economic costs. For example, the medical costs of treating health problems caused by air pollution can be substantial. The negative impact on tourism can also result in lost revenue for local economies (McLinden and Kumar, 2015). Furthermore, the loss of crop yields due to black soot can have a significant impact on agricultural economies, particularly in regions where farming is a major source of income. The negative impact on tourism can also result in lost revenue for local economies (McLinden and Kumar, 2015). The effects of black soot can also have political consequences. For example, air pollution and its associated health impacts can lead to increased public pressure for government action to reduce emissions. The economic impacts of black soot can also play a role in political decision-making, as governments seek to balance the needs of different industries and sectors. The effects of black soot are not limited to individual countries, as air pollution and its associated impacts can travel long distances and affect regions far from their source. For example, black soot from Asia can impact air quality and climate in North America, while emissions from Europe can impact Africa. This highlights the need for a global approach to reducing emissions and mitigating the impacts of black soot (Jeong et al., 2016).

According to EPA (Environmental Protection Agency in the US) identified black carbon as a major contributor to the fine particle (PM2.5) burden in the air. It is small enough to be easily inhaled into the lungs and has been associated with adverse health effects. Black carbon is associated with asthma, and other respiratory problems, low birth rates, heart attacks and lung cancer. EPA scientists study the effects of particles including black carbon on human health through clinical and animal testing.

Alani et al. (2018) in their work on the Impact of gas flaring on surface and underground water: a case study of Anieze and Okwuibome areas of Delta State, Nigeria reported that gas flaring is a major activity in oil exploration processes in Nigeria with concerns on its effects on the oil communities. The study investigated the contribution of flare gases to pollution burden of Anieze and Okwuibome communities. Water samples were displayed at 10-m, 50-m, and 100-m locations from gas-flaring stations, and control samples were taken in another location. After a month, the water samples were examined for heavy metals, polycyclic aromatic hydrocarbons, and physico-chemical parameters. Pb was found only in the 50-m location and above the WHO standard. Fe, Zn, and Cr were detected in the order 10 m > 50 m > 100 m > control whereas Cd was detected in the order 100 m > 50 m > 10 m > control. Fe, Zn, Cr, and Cd were linked to gas-flaring activities. The total PAHs were found in the order 10 m (1929.43 ?g/L) > 100 m (1759.64 ?g/L) > 50 m (620.27 ?g/L) > control (389.37 ?g/L). The signature ratio related the PAH sources to combination of petroleum and combustion sources. The sources of the PAHs were linked to the flare gas. Their study implicated gas-flaring activities for the increased pollution burden in the communities and suggested policies that guide its reduction in petroleum explorations.

Okorhi-Damisa et al (2020) also evaluated the effects of gas flaring on the physicochemical and hydrocarbons characteristics of water sources in Warri Metropolis, Delta State of Nigeria. Rainwater samples were collected from selected areas. All water sample results were compared with WHO standards for drinking water. The results revealed that water samples from the areas had considerable high levels of turbidity, total chlorine, nitrate, sulphates, lead, zinc, and copper with an acidic pH range of 4.50 to 6.30. All sampling sites also showed a high level of TPH contamination. TPH values ranged from 171.156mg/l to 241.947mg/l. The carbon chain length of aliphatics (n-alkanes) in the sampling areas was recorded from C8 to C40 dominated by heavy hydrocarbons (C36-C40), and the total n-alkanes ranged from 170.814mg/l to 241.891mg/l. The range of total PAHs compounds across the sampling areas was 0.343mg/l to 4.430mg/l. Therefore, gas flaring is a potential pollutant source in water, which could have an adverse health impact on the entire residents of (population) Warri and Ughelli metropolis and in other areas where this operation has been carried out.

Okhumode (2018), examine the burden of air pollution and emphasized that residents of Port Harcourt in Rivers State, Nigeria, and its environs have since the last quarter of 2016 been experiencing adverse environmental impacts of particle (soot) pollution. This “double air pollution burden”—the unresolved prevailing widespread air pollution and the “added” emergence of particle pollution considered an environmental health threat, led to protests against government inaction in some parts of the state. In February 2017, several months following the onset of the pollution, the government declared an Emergency, and set up a Task Force to investigate and find a solution to the problem. Global research suggests that particle pollution correlates positively with a range of morbidities and an increased risk of mortality among exposed populations. This underscores the need for rigorous implementation of existing environmental legislations established to protect the environment and public health. Nigeria’s rapid response to the 2014–2015 Ebola Virus Disease (EVD) and successful prevention of its spread provides some lessons for addressing such environmental health emergencies—strategic action, including effective environmental risk communication, environmental audit, and monitoring is key. Epidemiological studies of the affected population are imperative. A concerted effort by the Rivers State Ministries of Environment and Health, as well as academia and private organizations is required. Public service campaign in terms of government providing up to date information on the existing situation is required.

CONCLUSION

This review the impact of soot on the environment, livestock and the well being of inhabitants of the niger delta region, Nigeria, has exposed the adverse consequences of black soot on the environment and aquatic and terrestrial organisms in this region. All stakeholders are therefore called upon to intervent to stop the soot to preserve lives.

REFERENCES

1. Akpinar, S., Oztop, H. F., and Kavak Akpinar, E. (2007). Evaluation of relationship between meteorological parameters and air pollutant concentrations during winter season in Elaz??, Turkey. Environmental Monitoring and Assessment, 146(1-3), 211–224.
2. Alam M.S., Zeraati-Rezaei S., Stark C.P., Liang Z., Xu H. and Harrison R.M. (2016) The characterisation of diesel exhaust particles – composition, size distribution and partitioning. Faraday Discuss 189:69–84.
3. Alani, R., Nwude, D., Joseph, A., & Akinrinade, O. (2020). Impact of gas flaring on surface and underground water: a case study of Anieze and Okwuibome areas of Delta State, Nigeria. Environmental monitoring and assessment, 192(3), 166. https://doi.org/10.1007/s10661-020-8124-6
4. Aluko, M.A.O. (2005).The Impact of the Environment on Organizational Performance in selected Textile firms in Nigeria. Global Journal of Social Sciences, 4(1&2), 1-7).
5. Boffetta P., Jourenkova N. and Gustavsson P. (1997) Cancer risk from occupational and environmental exposure to polycyclic aromatic hydrocarbons. Cancer Causes Control 8(3):444–472
6. Bond, T. C., Doherty, S. J., Fahey, D. W., Forster, P. M., Berntsen, T., De Angelo, B. and Flanner, M. G. (2013). Bounding the role of black carbon in the climate system: A scientific assessment. Journal of Geophysical Research: Atmospheres, 118(11), 5380-5552.
7. Bond, T.C. and Sun, H. (2005). Can reducing black carbon emissions counteract global warming? Environ. Sci. Technol. 39:5921–5926.
8. Canagaratna, M. R., Onasch, T. B., Wood, E. C., Herndon, S. C., Jayne, J. T., Cross, E. S., Miake-Lye, R. C., Kolb, C. E., & Worsnop, D. R. (2010). Evolution of vehicle exhaust particles in the atmosphere. Journal of the Air & Waste Management Association (1995), 60(10), 1192–1203.
9. Cassee F.R., Heroux M.E., Gerlofs-Nijland M.E. and Kelly F.J. (2013) Particulate matter beyond mass: recent health evidence on the role of fractions, chemical constituents and sources of emission. Inhal Toxicol 25(14):802–812.
10. Cho Renne (2016). The damaging effects of black carbon. Columbia climate school, climate health and society. The Damaging Effects of Black Carbon (columbia.edu)
11. Chylek, P., Lesins, G., Kahl, J. D., Dubey, M. K. and Lohmann, U. (2006). Black carbon or brown carbon? The nature of light-absorbing carbonaceous aerosols. Atmospheric Chemistry and Physics, 6(11), 3245-3256.
12. Crouzet, Y.; Marlow, W.H. Calculations of the equilibrium vapour-pressure of water over adhering 50–200 nm spheres. Aerosol Sci. Technol. 1995, 22, 43–59.
13. EU Service for Foreign Policy Instruments (2019). EU Action Sheds Light on Black Carbon Emissions. https://fpi.ec.europa.eu/eu-action-sheds-light-black-carbon-emissions-2019- 08-27_en
14. Ghorani-Azam, A., Riahi-Zanjani, B., & Balali-Mood, M. (2016). Effects of air pollution on human health and practical measures for prevention in Iran. Journal of research in medical sciences : the official journal of Isfahan University of Medical Sciences, 21, 65. https://doi.org/10.4103/1735-1995.189646
15. Hesterberg, T. W., Long, C. M., Bunn, W. B., Lapin, C. A., McClellan, R. O., & Valberg, P. A. (2012). Health effects research and regulation of diesel exhaust: an historical overview focused on lung cancer risk. Inhalation toxicology, 24 Suppl 1(s1), 1–45. https://doi.org/10.3109/08958378.2012.691913
16. Ishihara, Y., & Kagawa, J. (2003). Chronic diesel exhaust exposures of rats demonstrate concentration and time-dependent effects on pulmonary inflammation. Inhalation toxicology, 15(5), 473–492. https://doi.org/10.1080/08958370304464
17. Jeong C., Kumar K. K., and Lee K. H. (2016) "Black carbon and the environment: a global overview".
18. Kim, S. and Kates, R. (2003). Climate and culture: An exploration of the relationships between physical climate and human values, beliefs, and practices. In Climate Change and Globalization: Double Exposures (pp. 89-108). Routledge.

19. Levitsky Michael, (2011). Black carbon and climate change considerations for international development agencies.
20. Liu S., Xia X., Zhai Y., Wang R., Liu T. and Zhang S. (2011) Black carbon (BC) in urban and surrounding rural soils of Beijing, China: spatial distribution and relationship with polycyclic aromatic hydrocarbons (PAHs). Chemosphere 82(2):223–228.
21. Luo, X., Bing, H., Luo, Z., Wang, Y. and Jin, L. (2019). Impacts of atmospheric particulate matter pollution on environmental biogeochemistry of trace metals in soil-plant system: A review, Environmental Pollution, Volume 255, Part 1, 113138, ISSN 0269-7491, https://doi.org/10.1016/j.envpol.2019.113138.
22. Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. Frontiers in public health, 8, 14. https://doi.org/10.3389/fpubh.2020.00014
23. Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. Frontiers in public health, 8, 14. https://doi.org/10.3389/fpubh.2020.00014
24. Masiello, C.A. New directions in black carbon organic geochemistry. Mar. Chem. 2004, 92, 201–213.
25. McLinden S.A. and Kumar K.K. (2015) Global economic impacts of reducing black carbon and tropospheric ozone emissions.
26. Okhumode H. Yakubu (2017). Particle (Soot) Pollution in Port Harcourt Rivers State, Nigeria—Double Air Pollution Burden? Understanding and Tackling Potential Environmental Public Health Impacts
27. Okorhi-Damisa, F.B., Ogunkeyede, A.O., Akpejeluh, P., Okechukwu, Leo (2013). Particle (Soot) Pollution in Port Harcourt Rivers State, Nigeria—Double Air Pollution Burden? Understanding and Tackling Potential Environmental Public Health Impacts
28. Pearce, D. (2002). Tourism and regional development: a research agenda. Tourism Management, 23(3), 361-366.
29. Pope, C. A. and Dockery, D. W. (2006). Health effects of fine particulate air pollution: lines that connect. Journal of the Air & Waste Management Association, 56(6), 709-742.
30. Prasad, R. and Bella, V. R. (2010). A Review on Diesel Soot Emission, its Effect and Control; Bulletin of Chemical Reaction Engineering & Catalysis, 5 (2, 69 – 86
31. Schmidt C. W. (2011). Black carbon: the dark horse of climate change drivers. Environmental health perspectives, 119(4), A172–A175.
32. Schmidt, M.W.I., Skjemstad, J.O., Czimczik, C.I., Glaser, B., Prentice, K.M., Gelinas, Y. and Kuhlbusch, T.A.J. (2001) Comparative analysis of black carbon in soils. Global Biogeochem. Cycle. 15:163–167.
33. Schwartz, J. (2009). Fine particulate air pollution and daily mortality: a review of the epidemiologic evidence. Epidemiology (Cambridge, Mass.), 20(1), 13-22.
34. Suman, D.O.; Kuhlbusch, T.A.J.; Lim, B. Marine sediments: a reservoir for black carbon and their use as spatial and temporal records of combustion. In Sediment Records of Biomass Burning and Global Change; Clark, J.S., Cachier, H., Goldammer, J.G., Stocks, B.J., Eds.; Springer Verlag: Berlin, Germany, 1997.
35. Sydbom, A., Blomberg, A., Parnia, S., Stenfors, N., Sandström, T., & Dahlén, S. E. (2001). Health effects of diesel exhaust emissions. The European respiratory journal, 17(4), 733–746. https://doi.org/10.1183/09031936.01.17407330
36. S. EPA (2012). Report to Congress on Black Carbon, U.S. EPA Report EPA-450/R-12-001. U.S. Environmental Protection Agency, Washington, D.C.
37. UNEP, (2011), Towards a Green Economy: Pathways to Sustainable Development and Poverty.
38. United States Environmental Protection Agency (EPA). (2012). Report to Congress on Black Carbon. Department of the Interior, Environment, and Related Agencies Appropriations Act, 2010
39. Valavanidis A., Vlachogianni T., Fiotakis K. and Loridas S. (2013) Pulmonary oxidative stress, inflammation and cancer: respirable particulate matter, fibrous dusts and ozone as major causes of lung carcinogenesis through reactive oxygen species mechanisms. Int J Environ Res Public Health

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10(9):3886–3907.
40. Watanabe, N., & Kurita, M. (2001). The masculinization of the fetus during pregnancy due to inhalation of diesel exhaust. Environmental health perspectives, 109(2), 111–119. https://doi.org/10.1289/ehp.01109111
41. Witkowski D., Kondo K. and Vishwanathan G. (2013) Evaluation of the sooting properties of real fuels and their commonly used surrogates in a laminar co-flow diffusion flame; Combustion and Flame, 160 (6) (2013), pp. 1129-1141.
42. Woodruff, T. J., Darrow, L. A., & Parker, J. D. (2008). Air pollution and postneonatal infant mortality in the United States, 1999-2002. Environmental health perspectives, 116(1), 110–115. https://doi.org/10.1289/ehp.10370
43. World Health Organization (WHO) (2017). WHO Releases Country Estimates on Air Pollution Exposure and Health Impact. Available online: http://www.who.int/mediacentre/news/releases/2016/air-pollution-estimates/en/
44. Xavier Mari, Jérôme Lefèvre3, Jean-Pascal Torréton1, Yvan Bettarel1, Olivier Pringault1, Emma Rochelle-Newall1,4, Patrick Marchesiello3, Christophe Menkes5, Martine Rodier6, Christophe Migon7,8, Chiaki Motegi7,8, Markus G. Weinbauer7,8, and Louis Legendre7, 8Effects of soot deposition on particle dynamics and microbial processes in marine surface waters (2014). Analysis of soot in rainwaters around warri metropolis
45. Yakubu Okhumode H. (2017). Particle (Soot) pollution in Port Harcourt, Rivers state, Nigeria—double air pollution burden? understanding and tackling potential environmental public health impact
46. Zhan, C., Cao, J., Han, Y., Huang, S., Tu, X., Wang, P., and An, Z. (2013). Spatial distributions and sequestrations of organic carbon and black carbon in soils from the Chinese Loess Plateau. The Science of the total environment, 465, 255–266.
47. Zhang, R.; Khalizov, A.F.; Pagels, J.; Zhang, D.; Xue, H.; McMurry, P.H. (2008). Variability in morphology, hygroscopicity, and optical properties of soot aerosols during atmospheric processing. PNAS 105:10291–10296.
48. Zhao, F., Yang, W.M. and Wenbin, Yu. (2020). A progress review of practical soot modelling development in diesel engine combustion. Journal of Traffic and Transportation Engineering (English Edition).