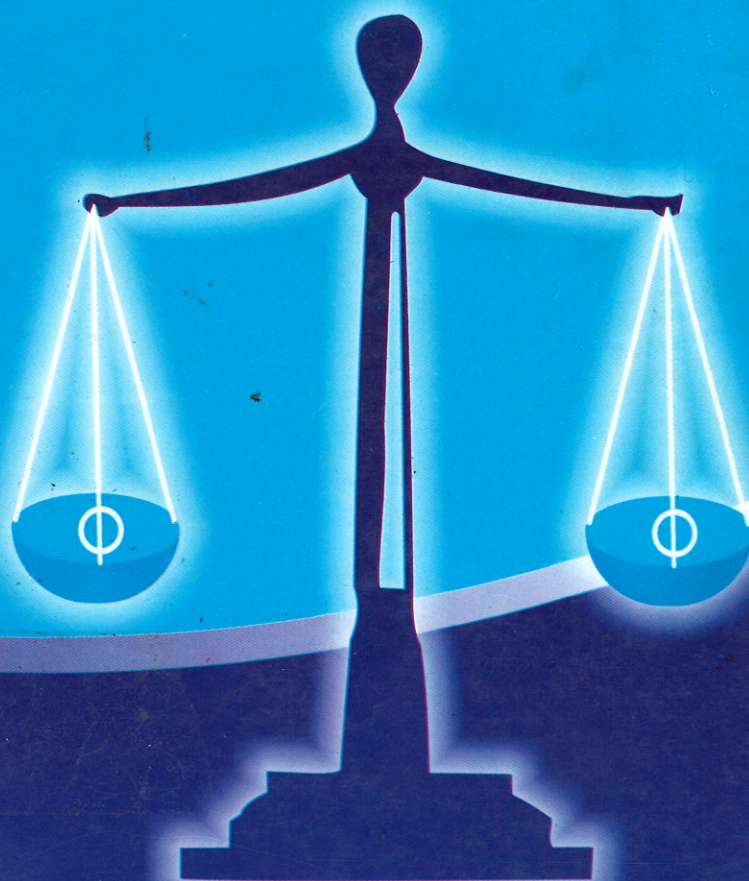


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UNDERSTANDING THE GLOBAL LEGAL RESPONSE TO AVIATION EMISSION: AN OVERVIEW OF THE GLOBAL ENVIRONMENTAL IMPACT OF AVIATION AND THE INTERNATIONAL LEGAL REGIME

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ABSTRACT

Throughout the world, aviation transportation is noted to be increasing steadily largely because globalization of world economy and economic growth, have made air transportation affordable for a large number of populations in the world.¹ The increase in growth of air transportation has led to increase in volume of aviation emission being discharged on the earth surface. This emission however, has severe consequences on the global environment in form of pollution of the atmosphere, stratosphere and lithosphere with high level of greenhouse gases like carbon dioxide, carbon monoxide, nitrogen oxide and others.² It has been observed that though aviation emission initially constitutes only 2% of the world's total greenhouse emission, it has now become the fastest growing source of anthropogenic greenhouse emission. This is because aviation emission from annex 1 countries rose by 67% between 1991 and 2005 and is estimated to rise by as much as 90% when aviation emissions from non -annex 1 countries are included for the period.³ The problem is that the potential threat of aviation emission to the global environment is said to be so much unless it is regulated. This paper therefore, analyses the contaminants of aviation emission and its impact on human lives and the global environment. It also discusses the international laws introduced to curb its escalating growth. The research finds that aviation emission has adverse consequences on human lives, local and the global environment and agree that it would require effective legal measures for its reduction. The paper recommends that effective implementation of the international legal regime will guarantee effective reduction of aviation emission.

Keywords: Examination, Contaminants, Aviation Emissions, Impact, Environment.

INTRODUCTION

Aviation emission is the gaseous substance emitted by air craft and aerospace as a result of their combustion activities. In all activities involving aircraft combustion, releases gaseous substance which contains carbon dioxide CO₂, carbon monoxide CO, vapour, sulphur dioxide SO_x, nitrogenous oxide NO_x, un-burnt hydro carbons, soot and

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¹David Freestone and Charlotte Streck, *The Legal Aspect of Carbon Trading, Kyoto, Copenhagen* Oxford University press, 2009, 27.

² Ibid.

³ Ibid, 28.

the atmosphere,⁴ through the burning of fossil fuels such as jet A for (turbine aircrafts) or gas for (piston air craft).⁵ The earth environment is the totality of the earth surroundings where human animals and non-living things exist to fulfil their desires. It is also the atmospheric surroundings where combustion and emission activities of air craft and aerospace engines take place.⁶ Therefore, accumulation of carbon emissions being released in large quantity into the atmosphere by several aircraft on international and domestic flights, over a long period of time, contributes in no small measure to inter-boundary and domestic pollution of the atmospheric environment, which later contribute to global warming and depletion of ozone layer with serious environmental consequences on human lives, animals and plants.

The primary products of aircraft combustion process whereby aviation fuel or aviation kerosene is sprayed and burnt in the chamber of aircraft are carbon dioxide and water vapour which constitute salient form of aviation emission. There is also the presence of nitrogen oxide and sulphur oxide, the emissions coming out of these gases are characterised as greenhouse gases (GHG) because when emitted into the atmosphere they trap the infrared radiation from the earth surface and make earth surface become warmer than before. The process of global warming of the earth surface which is equally aided by excessive discharge of aviation emission into the environment, takes place when certain gases which are below the atmosphere absorb the infrared radiation being sent down on the earth through energy from the sun. The direct energy from the sun which appears in form of light and cloud is being absorbed on earth through certain gases called Greenhouse Gases, which are naturally present below the earth surface. Reasonable quantity of greenhouse gases will keep the atmosphere in normal warm temperature but excessive release of greenhouse Gases into the atmosphere through burning of fossil fuel in the aircraft and other sources too much in the air, which cannot be absorbed by the earth surface. The heated earth surface in turn sends the heat energy back into the air space (upper atmosphere) which eventually leads to global warming of the earth environment.⁷ As regards depletion of ozone layer, the release of gaseous substance called aviation emission on the upper atmosphere by aircraft and aerospace engines on domestic and international flights has a direct impact on the depletion of ozone layer in the upper atmosphere. The consequences of which lead to acid rain, melting of glaciers skin cancer, air borne diseases destruction of forests, animals and plants.⁸

Worldwide, aviation transportation has been increasing steadily, largely due to globalization of world economy and economic growth which have made air transportation affordable for a large number of populations in the world.⁹ The increase in growth of air transportation has led to increase in volume of aviation emission being discharged on the earth

Andress Doppelheuer, *Aircraft emission parameter modelling* (Air and Space Euro 34 Dopelliar) www.ease.eu.int, viewed 6th Feb. 2014.

Andu, H.I, Mustapha, I.A, & Akanbi, K.O n1, at. 291.

Andu, H.I, Mustapha, I.A, & Akanbi, k.o, "Climate Change: Legal Response to Aviation Emission in Nigeria", in *Law and Climate Change*, Egbewole W.O, Etudaiye M.A, & Olatunji, O.A (Ed), (Faculty of Law, University of Ilorin) 2011 at. 291.

Andu C.A, *Environmental Regulations in Nigeria: Understanding the National Environmental Standards Regulations Enforcement Act 2010*, at. 23.

David MC et al *Reducing Green House Gas Emission from aviation and Marine Transportation in sustainable energy pathways Programme and Institute*, University of California, at. 4.

David Freestone and Charlotte Streck, *The Legal Aspect of Carbon Trading, Kyoto, Copenhagen and beyond*, University press, 2009, at. 27.

surface. This emission however, caused severe consequences on the global environment in form of pollution of the atmosphere, stratosphere and lithosphere with high level of greenhouse gases like carbon dioxide, carbon monoxide, nitrogen oxide and others.¹⁰ It has been observed that aviation emission constitutes the fastest growing source of anthropogenic greenhouse emission. This is because aviation emission from annex 1 countries rose by 67% between 1991 and 2005 and is estimated to rise by as much as 90% when aviation emissions from non- annex 1 countries are included for the period.¹¹ It has also been observed that about 3% of both the United States and European Union's (EU) total greenhouse gas emission are from aviation emission. The E.U has forecasted that current growth in trend of emission from international flights using E.U's airports will increase by over 150% over 1990 level.¹² This prediction is corroborated by the information in the table 1.1.1 below. Further, it has been observed that the share of aviation to total global transportation emission is larger if non carbon dioxide emissions are added. The overall impact of aviation emission is however potentially double in the case of aircraft in the air because aircrafts emit greenhouse gases directly into the atmosphere.¹³

TABLE 1.1.1 GLOBAL AVIATION DEMAND (In billion km)

Year:	1990	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Quantity	200	800	1200	2000	3500	4000	5000	6000	7000	8000	9000	10000

Table 1.1.1 shows the increasing trend of global aviation demand (1990-2100) in billion Km.

The impact of aviation emission on the environment is said to be more evident in correlation between increase in carbon dioxide (CO₂) emission and increase in average temperature observed over entire planets. Since 1860, the beginning of industrial era, the average temperature on the surface of the earth has increased by 0.8°C. The sudden rise in average temperature since the start of industrial era, is said to be abnormal compared with trends, but in view of its relative amplitude and the speed of change on geological time scale.¹⁵ Therefore, scientific studies have suggested that reducing global emission by 50 to 80 percent below 1990 levels by year 2050 is necessary in order to stabilize the climate and avoid most destructive impacts of climate change.¹⁶ Based on the above, this paper intends to analyse the contaminants of aviation emission and the impact of aviation emission on human lives and the global environment as well as discuss the outline of the legal regime for its control. This approach will enable proper understanding of the impact of aviation emission on the environment.

¹⁰ Ibid.

¹¹ Id, 28.

¹² David, M.C. et al, n. 7, at. 5.

¹³ Ibid

¹⁴ Vedantham .A. & Oppenheimer .M. Aircraft Emission and the Global Atmosphere University Pennsylvania at. 5 <[scholarly common repository open.edu/cgi/view_content.cgi?article1061&context=liberty](http://scholarly.commonrepositoryopen.edu/cgi/view_content.cgi?article1061&context=liberty)> [http%3A%2Fscholar.google.com.my%2Fscholargoogle.com.Environmental_Defensefund1994](http://3A%2Fscholar.google.com.my%2Fscholargoogle.com.Environmental_Defensefund1994)> 18/4/2014.

¹⁵ Ibid.

¹⁶ Id., 6.

environment and the justification for ensuring its reduction through the use of relevant legal measures.

THE CONCEPT OF AVIATION EMISSION

The concept of aviation emission needs to be examined in order to have an insight into aviation emission impacts the environment. The concept of aviation emission is however examined as follows:

Definition of Aviation Emission

Aviation emission can be explained as the gaseous pollutants emitted by air craft and aerospace engines as a result of their combustion activities. According to Oxford Advance Learner's dictionary of English, aviation emission is the sending out of carbon dioxide and other gases into the atmosphere by aircraft.¹⁷ Also, according to the report of Global Aviation Emission Inventories, aviation emissions are described as the smoke pollutants or gases from aircraft which originate from fuel burnt in air craft engines¹⁸ Further, the Kyoto Protocol to the United Nations Frame work Convention on Climate Change, though did not define aviation emission, brings to our awareness about the existence and limitation of aviation emission when it states in article 2 (2)¹⁹ that; "parties shall pursue limitation of reduction of emission of greenhouse gases not controlled by Montreal protocol from aviation by working through International Civil Aviation Organization. In all activities involving aircraft combustion, aircraft releases gaseous substance which contains carbon dioxide CO₂, carbon monoxide(CO), water vapour, sulphur dioxide SO₂, nitrogen oxide NO_x, unburnt carbons, soot and aerosol into the atmosphere, through the burning of fossil fuel such as jet A for (turbine aircrafts) or Av gas (for piston aircraft)²⁰. Therefore, the above shows that the emitted pollutants from aircraft emanating from the burning of the various gases above, are referred to as aviation emission.

Scope of aviation emission

In a broad sense, the scope of aviation emission under a typical aviation industry, extends beyond emission from air craft engines and aviation technologies to include emissions from ground airport vehicles and those used by passengers and staff to access airport, as well as through emission generated by production of energy used in airport buildings, the manufacture of aircraft and construction of airport infrastructure.²¹ However, for the purpose of this research, our focus of aviation emission shall be limited to emissions from civil aviation aircraft engines and aerospace engines only and even excluding military aircrafts. Specifically,

¹⁷ Hornby A.S, Oxford Advance Dictionary, International Student Edition, Oxford University Press 2012 at 45.

¹⁸ ANCAT/CC2, Global Aircraft Emission Inventories for 1991,1992 and 2015, Report by the ECAC/ANCAT Working Group Ed R Gardener ISBN 92828-2914-6 Netherlands 1998..

¹⁹ Kyoto Protocol to the United Nations Frame Work Convention on Climate Change, UN. DOC UNFCCC/KP/1977 at 21.

²⁰ Oluwalade, H .I, Mustpha I .A, & Akanbi K .O, "Climate Change, Legal Response to Aviation Emission in Nigeria" in *Law and Climate Change*, Egbewole W.O, Etudaiye M.A, & Olatunji, O .A, (Ed), (Faculty of Law, University of Ilorin) 2011 at 291.

²¹ Pachuri P .K. and Reiseinger A. (ed), *Climate Change Synthesis Report. Contribution of Working Group I and II to the Fourth Assessment Report of the Inter Governmental Panel on Climate Change*, (IPCC, Geneva, Switzerland, 2007) 104

this study will focus on emission emanating from civil aviation air craft engines being accounted and reported for under the regulations of International Civil Aviation Organization which is the body responsible for regulation of aviation emission.

THE CONTAMINANTS OF AVIATION EMISSION

Contaminant is defined as biological, chemical or physical substance which in sufficient supply can adversely affect living organism and the environment.²² By nature aviation emission is in the form of gaseous pollutants which are made up of greenhouse gases and other pollutants that affect the living and the environment. The role of Greenhouse gases which form the major part of aviation emission is explained below:

Greenhouse gases

According to Oxford Advanced Dictionary of English²³, Green house in technical context, is used to explain the atmosphere play in warming the earth surface. Short wave radiation passes through the atmosphere and absorbed by earth surface, this is then re-emitted and reflected back to the atmosphere by gases like carbon dioxide,, methane, nitrous oxide and ozone etc which are known as greenhouse gases. Also, the Special Assessment Report (1999)²⁴, of Intergovernmental Panel on Climate Change while reporting on the effect of aviation emission on global warming, refers to greenhouse gases as the cause of global warming. According to the report, such greenhouse gases as carbon CO₂, nitrogen oxide NO, water vapour H₂O, Sulphate aerosol and soot cause global warming when emitted from aircraft engines. Further, according to Thornton J. Beckwith S, greenhouse gases which are responsible for maintain the earth's relative warm temperature. But too much of trapping of the warmth from the sun in the lower atmosphere caused by too much presence of greenhouse gases such as carbon dioxide ,methane, nitrous oxide and others in the lower atmosphere leads to global warming.²⁵ Generally, greenhouse gases (GHGs) are a term used for gases which cause global warming of the earth, although (GHGs) production occurs naturally, greenhouse gases are majorly produced by burning of fossil fuel such as coal, oil gas, petrol, and kerosene.²⁶ The use of fossil fuel which has contributed immensely to industrialization and economic development, has also caused a steady increase in the release of high level carbon gases and other pollutants into the atmosphere. These greenhouse gases when emitted into the atmosphere, are like blankets, and are known for trapping heat in the atmosphere instead of allowing it to radiate back in to the space. As a result of this, the atmosphere is over heated at an abnormal rate and this leads to global warming and a change in weather pattern. In the combustion process, aviation fuel (kerosene) is sprayed at high pressure into the combustion chamber of the jet engine where it mixes with hot high pressure air supplied by the compressor and when ignited, the products of this process are carbon dioxide and water vapor which characterize the greenhouse gases, because when emitted into the atmosphere they cause global warming.

²² Business Dictionary <www.businessdictionary.com/contaminant/html, accessed 20/1/2016.

²³ Hornby A.S, n1 at 85.

²⁴ Intergovernmental Panel on Climate Change (IPCC) , The Assessment Report 1999, < <http://www.ipcc.ch> accessed on 20/1/15.

²⁵ Thornton J, and Beckwith, Environmental law, Sweet and Maxwell, London 2010, at 3.

²⁶ Hassen J. E, Defusing the Global Warming Time Bomb, Scientific American publication Washington DC, 2000, at 68.

²⁷ Ibid

natural greenhouse effect by trapping the infrared radiation from the earth surface.²⁸ The greenhouse effect is a natural phenomenon that warms the earth to support life and without it, the earth temperature will be a frozen -18⁰c (Celcius) instead of normal/average of +15⁰c.²⁹ The greenhouse effect is believed to cause abnormal warming of the atmosphere leading to melting of the polar ice caps and flooding of the low land mass. The major greenhouse gases and other pollutants which form the components of aviation emission and contribute to global warming and other atmospheric changes, are explained as follows:

Carbon dioxide (CO₂)

Carbon dioxide is a gaseous pollutant in aviation emission which contributes to global warming and climate change. It is estimated that the current world wide fleet of air craft produces about 2 to 3% of the fossil fuel released into the atmosphere.³⁰ According to report, the combustion of one kilogram of aviation emission kerosene directly results in emission of about 3160 grams of CO₂ into the atmosphere. Carbon dioxide (CO₂) is believed to have a very long atmospheric residence time (approximately 100years) and CO₂ emitted from air craft becomes well mixed with CO₂ from other fossil fuel sources.³¹ Since the effect of CO₂ on climate change is direct and depends on atmospheric concentration, aviation emission of CO₂ will continue to be a matter of environmental concern in view of projected growth in aviation emission.

Nitrogen Oxide (NO_x)

Nitrogen Oxides are part of greenhouse gases. Nitrogen oxides and oxygen are readily formed by direct reaction of nitrogen and oxygen in high temperature combustion process that occurs in jet engine aircraft because, air contains 78% of nitrogen and 21% oxygen.³² This combustion process produces several oxides of nitrogen like nitric oxide (NO_x) and nitrogen dioxide (NO₂) both termed as (NO_x). This nitrogen oxide (NO_x) is known to have great influence in the chemistry of troposphere and atmosphere especially in ozone production and destruction processes.³³ A natural occurrence of gas in the atmosphere which about 80 -90% reside in the stratosphere is known as ozone. This is produced by reaction of oxygen molecules and ultra violet radiation (UV) from the sun in a process called photo dissociation.³⁴ Chemical reaction in a pollution free atmosphere ensures a balance between production and destruction of ozone which leads to a steady state of abundance of gas in the stratosphere and this is called ozone layer.³⁵ The ozone layer doubly acts as the shield that protects biological system on the earth surface from damaging ultra violet radiation from the sun and also acts as a

²⁸ G.P Brasseur et al, "European Scientific Assessment of the atmospheric effects of air craft emissions" Vol. 22 No 13 (2001) *Atmospheric Environment* pub,2332.

²⁹ Paul Stephen Dampsey, "Trade and Transport policy in Inclement Skies: The Conflict Between Sustainable Air Transportation and Neo classical Economics," (2000) 65 *J Air & L Com*, 639.

³⁰ Joyce E. Penner et al, eds, *Aviation and Global Atmosphere; Special report of Inter Governmental Panel on climate Change*, Cambridge UK, Cambridge University Press 1999, at 3 .

³¹ Ibid,4.

³² Penner ,n9 at 23

³³ Ibid

³⁴ Albritton et al, "Global Atmospheric Effects of Aviation: Reports of the Proceeding of The Symposium," (2001), NASA Publications Washington DC, 8.

³⁵ Ibid.

greenhouse gas but its efficiency in this role depends on its altitude and latitude. Therefore, a discharge of nitrogen oxide in the upper stratosphere from aviation emission, has a profound effect upon atmospheric ozone. In addition, nitrogen oxide emissions below cloud level are washed out of the atmosphere as acid rain.³⁶

Methane

Methane is another pollutant of aviation emission among the greenhouse gases. Though, not emitted in large quantity like carbon dioxide, methane also plays an important role in atmospheric changes through reactions with nitric oxide and other hydro carbon products. Methane is known to represents 15% to 20%³⁷ of man-made additions to global warming, despite the fact that methane only lasts for a period of ten years in the atmosphere, it absorbs twenty to thirty times more heat than carbon dioxide. Methane has warming effect on the atmosphere and too much presence of methane in the atmosphere from aircraft emission has global effect on climate change.³⁸

Water Vapour (H₂O)

Water vapour is a pollutant which constitutes an active radiative gas in aviation emission, therefore, additional water vapour in the atmosphere can directly modify the radiative capacity of the earth by enhancing greenhouse effect.³⁹ Water vapour which is another primary product of combustion in air craft jet engine however has its effect on the atmosphere influenced by its altitude. The potential climatic effect of water vapour emission by air craft in this respect, depends on the relative contribution of the emission to the background water vapour level in the atmosphere.⁴⁰ Water vapour H₂O, is emitted by very large air craft in flight at high altitude. Emission of water vapour from aircraft engines in conjunction with soot and sulphur compounds, form condensation nuclei⁴¹ and trigger additional cloud formation in the atmosphere which indirectly contributes to radiative forcing⁴² and climate change. Condensation nuclei forms when soot particles present in the air craft emissions are activated, these condensed water vapour keeps growing in size until clouds are formed. These clouds called condensation trails or contrails may not stay long and may be persistent in the atmosphere based on the background temperature and high humidity level.⁴³ Whenever the air is super saturated with water and temperature is below freezing point, formation of persistent contrail with longer residence period in the atmosphere takes place Water vapour is considered

³⁶ J. L Cornish, J. A Nicel & A.D Groenewe, "Transport Canada: the Greening of aviation (Montreal)" (1996) QC Transportation Development Centre, 28.

³⁷ Barret M, Aircraft Pollution: Environmental Impacts And Future Solutions, WWWR Research paper publications, London 2007 at 7

³⁸ Ibid, 8

³⁹ Brasseur, n5, 33.

⁴⁰ Ibid.

⁴¹ Condensation nuclei means cloud compression, cloud cluster or gathering of cloud.

⁴² Radiative Forcing (RF) is a change in average net radiation at the top of troposphere resulting in solar and infra red radiation. It is a measure of warming and the rate of energy per unit area of the globe as measured at the top of the atmosphere and its expressed in unit of watts per square metre. When radiative forcing is evaluated positive, it will lead to warming of the atmosphere but when negative, it will have cooling effect on the atmosphere see Green Growth and the Future of Aviation, paper prepared for 27th Round table on sustainable development, Organization for Economic Cooperation and Development, London 2012 at 5

⁴³ A.W Brewer, Condensation Trails vol.1, Weather publication, 1964 at 34

in determining radiative balance and chemical composition of atmosphere because of the dramatic role it plays in polar ozone loss through formation of polar stratospheric cloud.⁴⁴

Sulphur Oxide (SO_x)

Some amount of sulphur about 0.04 – 0.05 % is contained in a standard jet engine fuel (Aviation kerosene).⁴⁵ In a combustion process, the oxidation of fuel sulphur leads to production of sulphur dioxide (SO₂) which further reacts with other species in the exhaust of plane to produce sulphur trioxide (SO₃) and possibly sulphuric acid (H₂SO₄).⁴⁶ The atmosphere will be affected by these oxides of sulphur by increasing sulfate aerosol level, thereby enhancing heterogeneous processing of halogen reservoir gases and by reactivating carbon soot particulate to bring about condensation nuclei which will bring about an increase in the formation of contrails and cirrus clouds.⁴⁷

Carbon monoxide (CO)

Carbon monoxide is a poisonous gas contained in aviation emission. It is not a greenhouse gas contributing to climate change, but a product of incomplete combustion with a particular concern to the health of people in urban environment. CO reduces the atmosphere's hydroxyl content which acts as nature's detergent. Carbon monoxide is known to be a common irritant when emitted as a surface level pollutant, it is primarily generated by aircraft at low engine power level at idle or taxi time by aircraft.⁴⁸

Products of incomplete Combustion

Due to incomplete combustion of fuel, air craft engines emit a number of effluents which include volatile organic compound (VOCs) such as benzene, toluene formaldehyde and 1,3-butadiene.⁴⁹ There are also non-methane hydro carbons (HC) such as alkaline aldehydes and acetone, carbon monoxide (CO) and carbon soot (smoke).⁵⁰ Soot is generated at high engine power level while hydro carbon and carbon monoxide are generated at low engine power level. The quantity emitted by any air craft engine however depends on the combustion efficiency of the engine. The atmospheric effects of products of incomplete combustion are however mostly localized. For instance, soot and unburnt hydro carbons are responsible for poor air quality and smog around airport while carbon monoxide is a common irritant emitted as a surface level pollutant. As a matter of fact initial concern about atmospheric impact of air transport focused on these localized environmental problems.⁵¹

THE IMPACT OF AVIATION EMISSION ON THE ENVIRONMENT

It is observed that the above discussed contaminants of aviation emission have serious impact on human health. Not only that, the contaminants also have serious local, regional and

R.C Brown et al, "Air craft sulfur emissions and the formation of visible contrails," (200) Vol. 3603 *Geography Research Letters*, 23

Abtinton et al n11 at 67.

Dampsey n 28 at 645.

Britton et al, n69 at 10.

global effects on the environment. However, before discussing about the impact, the concept of environment shall briefly be discussed for the purpose of better understanding of discussion on the impact.

Concept of environment

Environment can be explained as the constituent of the totality of the earth surroundings which includes the land, the sea, the air, the vegetation and human life. The earth is therefore a source of human sustenance that human beings depend upon for food, fuel machine material and even spiritual material.⁵² The English language term "Environment" is known to be borrowed from French word "environner." Webster dictionary defines environment on the original French meaning as "circumstances, object or condition by which one is surrounded". It states further that environment is the complex physical, chemical and biotic factor, including climate, soil and living thing or an ecological community and untimely determine its form and survival.⁵³ In law content, environment may relate to a limited area or the entire planet including atmosphere and stratosphere. The international court of justice defines environment to include social dimension, stating that environment represents the living space, quality of life and the health of human beings including generation unborn.⁵⁴ However, the international legal instruments have referred to environment to include water, air, land and their inter relationship as well as relationship between them and living organism. Specifically, the United Nations Stockholm Conference on Human Environment (UNCHE) 1972,⁵⁵ refers to man's environment as that which gives him physical sustenance and affords him opportunity for intellectual, spiritual, moral and social growth, adding that both the natural and manmade environment are made essential for wellbeing of human life. From the above, it can be understood that the environment is the atmospheric surrounding where human beings animals and plants survive and the scope of environment includes water, air and land. In the context of this study, this same environment is referred to as the surrounding where combustion and emission activities of aircrafts and aerospace engines take place. On the other hand, impact shall simply be explained to mean the effect, the result or consequences of an action. Based on the above, the impact, the effects or negative consequence of aviation emission on the state of earth environment shall now be discussed.

Aviation plays a significant role in social and economic life today, in the sense that it provides a quick, reliable and safe means of transportation to people whether for business holidays or family tours. Besides, aviation offers easy access to remote areas of the globe and has virtually turned the whole world into a global village. Aviation also shortens travel time considerably when compared to other types of travelling. Because aviation enables goods and services to be transported to their destinations quickly, it has contributed to increase in the volume of import and export of goods in the world.⁵⁶ Altogether, aviation accounts for 1 billion air lines passengers in year 2000, over 29million tonnes of freight in 1998 while 40 %

⁵² Murtala A.G, "An Appraisal of the Legal Regime Regulating The Earth Environment in Nigeria" (unpublished LLM thesis, Faculty of Law, University of Ilorin, Nigeria) 2010, 17.

⁵³ Environment defined in Ninth New Collegiate Dictionary (2008).

⁵⁴ Ibid

⁵⁵ Stockholm Declaration on Human Environment (UNCHE) June 16 1972.

⁵⁶ Cordina E, "Aviation Emission and the Environment: A Study on Ways to Limit the Environmental Damage caused by Engine Emission and an Assessment of Future Environmentally Friendly Aircraft Technologies,(Masters thesis in air transport management, London University, 2002) ,1.

value of world manufactured goods are transported by air as at today. In 1993, the world airline made an annual turn-over of US \$307 billion while aviation industry generated employment of over 28 million world-wide in year 2000 and many jobs also created as a multiplier effect in relevant sectors like hotels, travel agencies and car hire services.⁵⁷ However, it is important to note that despite the tremendous benefits mentioned above, aviation industry has its bad side in the sense that aviation emission being generated by aircraft engines during air transportation has a negative impact on the environment both at local and global levels.

Local and Regional impact of aviation emission

By local and regional impact of aviation emission, we mean the domestic or national impact as well as international impact of aviation emission on the environment. The above is discussed as follows:

Pollution of air environment around airports

In the environment around the airports, emission of gaseous and particulate products from aircraft jet engine during landing and take-off cycles had for long been recognized as a strong factor contributing to urban smoke problem and photo chemical smog generation.⁵⁸ The level at which aircraft exhaust emission within the airport and airport neighbourhood has great influence on the environment around the airport as emission of critical gases has critical effects on climate process of the area. Emission of carbon monoxide from aircraft engines are the peak when aircraft is stationary at the airport. Carbon monoxide when combined with haemoglobin in blood to form carbon haemoglobin will reduce oxygen capacity of the blood and dangerous to the body when inhaled in large concentration as this may lead to high rate in death of human beings and animals living around the airports.⁵⁹ In the 1990s, a number of published epidemiological studies found association between elevated level of air pollution on one hand, mortality and respiratory health care symptoms on the other. Although, there were some disagreements over the nature of the symptoms, some effects manifested in lung function deficits, to aggravation of symptoms of asthma while some effects emerged only after long term cumulative exposure.

It has also been recognized that the environment and the people living around the airports are subjected to serious problem of environmental odour by aviation pollutants like sulphur dioxide SO_2 and ground level ozone caused odour problem, especially when mixed with serious odour from aviation kerosene.⁶⁰ This type of environmental odour is known to be harmful to lungs, reduce resistance to infection and aggravate heart disease, asthma and bronchitis.⁶¹ A relevant example is that of Chicago O'Hare international airport which its annual record of 900,000 flights operation, ranks it as one of the top of five toxic pollution source in the state of Illinois, in America.⁶²

⁵⁷ Albritton et al, n81, 29.

⁵⁸ Allan Wellburn, *Air pollution and Climate Change, The Biological Impact*, 2nd ed, Harlow, UK, Longman, 2002, at 202.

⁵⁹ Sophie S. "The Environmental impact of Aeronautic activities, Legal Aspects", (Unpublished LLM thesis, Faculty of Air and Space Law MC Gill University Montreal Canada, 1993), 23.

⁶⁰ Dempsey, n28 at 21.

Particulate like soot is known for contributing to formation of smog and hazes around the airport and urban areas which reduce visibility during vehicular movement. This formation also destroys the soil and aesthetic value of buildings and properties around the airports. Hydro carbons like Benzene and other related carbons are carcinogenic when emitted from aircraft engines and persistent exposure to these carbons by human beings is deadly.⁶³ For example in 1993, aircraft at US air ports produced 350million pounds of VOCS and NO_x during their landing and take-off cycles (LTOs), more than twice their 1970 level. An airport arriving and departing aircraft, creates much if not more than ground level VOCs and NO_x than their industrial neighbours. This type of development portends a dangerous impact to the people and the airport environment in the United States of America.⁶⁴

Trans boundary air pollution and acid deposition

Aviation emission impacts on the environment through trans boundary air pollution in the sense that notable oxides of sulphur and nitrogen which are observed to have capacity to remain airborne for several days or travel through a number of kilo meters, contribute greatly to secondary pollutants that damage the environment when transported and emitted into the air of another country by aircraft engines. This is the case when sulphur oxide and nitrogen oxide normally oxidize to form sulphates and nitrate particulates which also precipitate independently into a dry fall or combine with cloud vapour to form sulphuric nitric acid and subsequently precipitating as snow into acidic wet fall.⁶⁵ Occurrence of dry fall can be localized, whereas occurrence of acidic wet fall may occur at a considerable distance away from original source of emission. The fact that these oxides have the capacity to remain airborne for several days and travel thousand kilo meters before being deposited has made it possible for the oxides to be transported and deposited on trans boundary basis via aircraft engine emission with devastating consequences on the lives of people and the environment of the deposited country in other jurisdiction. Despite remarks that air craft engine emission makes only a minimal contribution to long range pollution, the fact still remains that aircrafts are non stationery sources of long range pollution and also the fact that aircrafts emit these oxides into the atmosphere directly at high altitude, reinforces the capacity of the oxides to stay for longer period in the atmosphere and to be transported over long distance.⁶⁶

Acid deposition by aircrafts through long range air craft emission, usually results into acid rain which has serious acidizing consequences on forests, wet land, and river courses. Acidizing of river courses has serious effects on fish and water lives. Leaching of plant nutrients and radiation in forest productivity especially at altitude over 600 meters are the serious effects of acid deposition in forest areas.⁶⁷ Also, acid deposition and acid rain have serious corrosive effect on metal monuments and historic buildings, thereby affecting the environment.

⁶³ Sophie, n37 at 2

⁶⁴ Dempsey, n49 at 23.

⁶⁵ Okowa P.N, *State Responsibility for Transboundary Air Pollution in International Law*, Oxford University Press, 2000, at 7.

⁶⁶ Runwatissa I.R.A, "Aircraft Engine Emission and Noise", (1999) *Environmental policy and Law*, 239

⁶⁷ Derek M.E, *Atmospheric Pollution; A Global Problem 2nd ed*, Oxford UK:Blackwell,1992, 100

GLOBAL IMPACT OF AVIATION EMISSION

The global impact of aviation emission globally impacts on Climate Change, haze, acid rain and atmospheric ozone concentration as follows:

The impact of aviation emission on Climate Change

Aviation emission impacts a lot on Climate Change because international aviation has been experiencing fast growth and this growth is known to be connected with socio economic and environmental harm which centres impact on climate change. A change of climate or climate change is that which alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods. It is a change in the statistical distribution of weather over period of time that ranges from decade to millions of years. It may be a change in average weather, or a change in distribution of weather events and may be associated with a specific region or occur across the whole hearth and it is presently known as a change in modern climate.⁶⁸ The UNFCCC describes climate change as an alteration in the atmospheric temperature caused by greenhouse gas which is accumulating in the earth's atmosphere as result of human activities and which cause surface air temperatures and subsurface ocean temperature to rise.⁶⁹ However, climate change is a wider phrase which includes global warming as one the extreme weather events arising out of climate change. Consequences of climate change which according to Intergovernmental Panel On Climate Change include rising temperature and extreme weather, disaster such as flood and draughts have already affected millions of people.⁷⁰ There is also, illness, loss of forest and biodiversity, displacement of communities and socio economic decline all of which will be hardest on the poor and the developing countries.⁷¹ Climate change is predicted to lead to variety of other impact such as melting of glaciers and mountain snow cap, a rise in sea levels due to melting of glaciers, extreme bad weather, lower agricultural productivity, increase in vector borne diseases and extinction of higher level species.

Aviation emission globally impacts on the environment by bringing about global warming which changes the radiative balance of the atmosphere and eventually lead to climate change. It also impacts on human health by adversely affecting the air quality as explained above.⁷² However, an efficient understanding of the impact of aviation emission on climate change will rely on clear understanding of contribution of aviation emission to climate change as contained in the published reports of Intergovernmental Panel on Climate Change from 1990 - 1999.

According to the comprehensive report of IPCC (1999) on the effect of aviation emission on global atmosphere, the aviation sector represents approximately 3.5 % of the total anthropogenic radiative forcing which was a great measure of warming.⁷³ This was caused by a group of Green House Gases emitted from aircraft engines mainly (CO₂ and NO_x,

Fagbohunge O and Nlerum F, "Law and Climate Change in Nigeria", in *Law and Climate Change*, Olowole W.O, Etudaiye M.A & Olatunji O.A (Ed), (Faculty of Law, University of Ilorin) 2011, 241.

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Nicholas Simeon, "Development of a Rapid Aircraft Estimation Tool with Uncertainty Qualification" (MSc Thesis, Aeronautics and Astronautics Massachusetts Institute of Technology, Massachusetts), 2013, 40.

Vedantham & Michael Oppenheimer, *Aircraft Emission and Global Atmosphere Environmental Science Fund*, 1994), at [32 :59] < www.works.Bepress.com/anu/37 > viewed 14/12/2014.

water vapour, sulphate, aerosol and soot). Aviation emission was estimated to increase to 5 percent in 2050.⁷⁴ Several other researches carried out since 1999, confirmed this position and stated that aviation emission has been projected to increase above 35% due to expected growth in air travel.⁷⁵ Although, 3.5% radiative forcing may be said to be low comparatively, severity of aviation emission which may be explained by considering the following three factors:

- Air craft emissions are injected directly into the upper troposphere and lower stratosphere and the impact of burning fuel at altitude is about double than burning fuel on the ground.
- The impact of burnt mixture of emission species was calculated to be two or four times more than exhaust of carbon dioxide alone from aircraft, causing radiative forcing.
- The rapid growth in aviation sector is expected to continue as globalization of industry and commerce progresses.⁷⁶
- Further, the fourth assessment report of IPCC fixed total air transport CO₂ emission at 280mt in 2000 and 282Mt in 2005. It was forecasted in the report that such emission will be 584 Mt in 2010, 860 Mt in 2020, 1262 Mt in 2030 and 2377 Mt in 2050.⁷⁷ Also report from International Air Transport Association (IATA) 2010 indicated that air travel and freight volume have increased tremendously.

Air lines are expecting to have 16 billion travellers and handle 400 million tons of cargo in 2050 (a strong growth from 2.4 billion passengers and 43 million tonnes of cargo).⁷⁸ The above shows the increasing of growth of aviation emission and its corresponding impact on global warming as crystallized by greenhouse effects. It also shows the need for urgent reduction in aviation emission as a way of combating climate change. However, further understanding of the impact of aviation emission on climate change, can be appreciated by a careful examination of the negative contributions of carbon dioxide water vapour and other processes of aircraft engine emission to global environment.

Aircraft emission contains carbon dioxide with serious global warming impact on the environment. Carbon dioxide CO₂, has a significant warming effect on the environment. Carbon dioxide is relatively straight forward to estimate as it is effectively a direct function of aircraft fuel burn. Aviation emission represents 2.25% of total annual anthropogenic human induced carbon dioxide emission at the global level, according to International Energy Agency statistics. At present, carbon dioxide accounts for 0.9% of cumulative anthropogenic emissions since the pre industrial era because affordable mass air travel is relatively a recent phenomenon.⁷⁹ The impact of concentration of Carbon dioxide emission in the atmosphere reported above is warming of the earth surface, melting of the glaciers and adverse climate change consequences.⁸⁰

⁷⁴ Ibid

⁷⁵ Id, 33.

⁷⁶ Id, 34.

⁷⁷ Id, 35.

⁷⁸ Id, 36.

⁷⁹ Airport Commission, "Discussion Paper 03, Aviation and Climate change", (Airport Commission 2013), 5.

⁸⁰ Ibid

Air craft emission produces water vapour with global warming impact on the environment. Water vapour (H_2O) is another pollutant emitted by very large aircrafts at high altitude with warming effect. Under a certain atmospheric condition, water vapour forms condensation contrails and visible lines that form in cold humid atmosphere and are known to have a global warming effect though not as much as that of carbon dioxide CO_2 and nitrogen oxide NO_x .⁸¹ In addition, the amount of dissolved oxygen in water is inversely related to temperature as such there will be less oxygen available for animals and plants at high water temperatures and a slight change in water temperature can alter the growth rates and species composition of aquatic organisms like fish.⁸²

Impact of aviation emission on Haze

Aircraft emission is responsible for formation of haze with global impact on climate change. It has been observed that mixture of particulates called soot and unburnt carbons emitted by air craft engines are responsible for poor air quality, smog and haze around the airports. Soot absorbs heat, it has a warming effect and influences the formation and properties of cloud globally.⁸³ This is also responsible for poor visibility in vehicular movements around the airports.

Impact of aviation emission on acid rain

It has been observed that aviation emission contributes to acid rain which has global effect on environment. Sulphur dioxide SO_2 emitted by air crafts, contributes to acid rain after mixing with Nitrogen dioxide and water vapour to produce sulphuric acid. Apart from being emitted at altitude, emission of sulphur below the cloud level washed away as acid rain. The effect of acid rain on the environment is that it causes severe pollution of water, acidify lakes, damage to, plants and animals in the environment, as well as corrosive effects on metals, monuments and buildings.⁸⁴ Acid rain is a major global problem. It is said to have caused decline of forest in central and Eastern Europe and many lakes in Scandinavia and Canada are now incapable of supporting life because of acidification. Lake acidification is known to have killed some fish population and can slow forest growth.

Impact of aviation emission on atmospheric ozone concentration

There is a good evidence that aircraft Nitrogen oxide NO_x emission affects climate change by producing ozone (O_3) with a warming effect and destroying methane (CH_4) with a cooling effect.⁸⁵ The observation which is restricted to the present commercial fleet of subsonic aircraft whose emission occurs in the upper troposphere and lower troposphere said that emission of nitrogen oxide NO_x by aircraft in the upper Troposphere (UT) / Lower stratosphere (LS) increases ozone concentration in those regions of the atmosphere, but similar emission in the upper stratosphere tried to deplete ozone, thereby minimally offsetting the NO_x induced increases with ozone of upper troposphere and lower stratosphere.⁸⁶ Although, the

Cardina Eric, n34 at 50.

Paul S. Dempsey, n39,7.

Black M. Elson, n43, 91.

degree of this occurrence is not yet quantified, it was estimated that in 1992, aircraft reduced the erythema dose rate of solar ultra violet radiation reaching the surface of the earth by 0.5% at 45degree North in July that year.⁸⁷ Comparatively, the calculated increase in erythema dose rate due to ozone depletion was about 4% over 1970 -1992 at 45% North in July.⁸⁸ The above appears to be an increase in column ozone and decrease in UV radiation reaching the surface of the earth. The impact of this is that the increase in Ultra Violet radiation (UV) is detrimental to human health as it leads to suppression of human immune system, sunburn. Skin cancer and cataract. It also reduces growth rate of forest and productivity of crop and disrupts aquatic life in the ocean.⁸⁹

It has been observed that aviation transport accounts for 43% of NO_x emission in the United States and 60% in Europe.⁹⁰ According to report, nitrogen oxide depletes ozone at higher altitude, while in another sense, below a level of 12km, NO_x increases the amount of ozone, acting as a potent green-house gas.⁹¹ In 1998, a published study in a scientific magazine, twenty four scientists concluded that air craft emission of nitric oxide interact with sunlight in the upper troposphere to produce ozone resulting in the formation of more green-house gas than previously thought.⁹² In Europe, tropospheric ozone has increased by 500% since 1970, concentrations are increasing one to two percent per year in Northern Hemisphere.⁹³

From all the above, it has been seen that aviation emission has adverse socio economic and environmental effects on the lives of people and the earth environment. It therefore requires necessary legal intervention to halt its further damage.

The Legal Regime

In realisation of the impact and bad consequences of increasing aviation emission on the environment, the international community responded to the adverse atmospheric effects of aircraft engine emission in two ways: One approach was to control aviation emission through ratification of international conventions and protocols by member states. The notable convention and protocol for this are the United Nations Framework Convention on climate change, UNFCCC (1992) and the Kyoto protocol to the UNFCCC (1997).⁹⁴ Under Public International Law principle, such convention and protocol are to be signed, ratified and domesticated by member states to become implemented as part of the domestic Acts of a state.⁹⁵ The other approach has been to address reduction in aviation emission directly from aircraft engines through the regulatory regime of International Civil Aviation Organization (ICAO). The regime include the Standard Recommended Practices on air craft engines

⁸⁷ Ibid

⁸⁸ Id,100.

⁸⁹ Hilborn J & M .Still, "Environment Canada: The Canadian Perspective on air pollution," (1990), *Ottawa state of Environment reporting*, 70.

⁹⁰ Paul S. Dempsey, n 28,6.

⁹¹ Ibid

⁹² Ibid

⁹³ Ibid

⁹⁴ Mankata Nyanpong Y.O. Regulation of Air craft engine emission from International Civil Aviation, (LLM thesis, Institute of Air Space Law. Faculty of Law, MC Gill University, Montreal Canada2005), at. 3.

⁹⁵ Abdul Gafur, H. *Public International Law: A practical Approach* (3rdEdn) Malaysia, Sweet and Maxwell Asia(2011), at. 78.

SARPs) and other regulations contained in annex 16 volume II of the Chicago convention 1944. The ICAO regulations equally need adoption into national regulations for the purpose of implementation by member states, in line with ratified convention.

The ICAO is the global organization responsible for regulation of international civil aviation. Its functions include making laws on international standard and best practices in aviation, which are to be implemented among member states. Based on this approach, the International Civil Aviation Organization (ICAO) has since June 1981 adopted a continually updated international standard and recommended practices on aircraft engine emission in exercise of its laws making power under article 37 of the Chicago Convention on international civil aviation 1944. The SARPs contained in annex 16 vol. II call for prevention of international oil venting and established standard for air craft emission control. Added to this, annex 16 volume II of Chicago convention limits certain aircraft emission through engine certification process, depending on the age and type of aircraft. It also established highly technical process for measuring emissions. The emissions under ICAO control include, smoke, hydro carbon, carbon dioxide CO₂ and Nitrogen Oxide NO₂ from new engines.⁹⁶ The above international conventions and regulations are however expected to be applied and implemented by member states of ICAO for achieving effective reduction in the increasing volume of aviation emission.

CONCLUSION

From the above, this paper has analysed the definition of aviation emission, the determinants of aviation emission. It also analysed the impact of aviation emission on human beings, the local and Tran's boundary environment, as well as the global environment. It is now clear from the above that contrary to the claim that aviation emission only contributes 2% of the total global emission and thus has little impact on climate change, aviation emission has a significant impact on climate change both locally and globally and this impact will continue to increase as a result of global increase in aviation transportation. It has been established that the ICAO's plea to continue to grow above 2% will constitute serious threat to the environment. It is also established that the impact of burning aviation fuel at altitude is about double than that of burning same fuel on ground. It has been noted that the impact from the mixture of emission from air craft goes beyond radiative effect of CO₂ alone, as the mixture of such gases was calculated to be two or four times more than exhaust of carbon dioxide alone from aircraft, as the mixture is known for causing radiative forcing. Also, it was observed that as globalization of industry and commerce increases, the fast growth of aviation sector is expected to continue. Added to the above, various reports have pointed to the fact that future scenario of air transportation and aviation emission shall continue to rise. The report of International Air Transport Association (IATA) 2010, indicated that air tr and freight volume increased tremendously and predicted 16 billion travellers and 400 million tons of cargo per lines in 2050.⁹⁷ The Intergovernmental Panel on Climate Change (IPCC), in its fourth assessment report, put total air transport carbon dioxide at 280mt in 2005 and later predicted such emission will be 594mt in 2010, 860mt in 2020, 1262mt in 2030 and 2377 in 2050.⁹⁸ The purpose of these reports is to show that as a result of continuous fast growth in global air

transportation, aviation emission will continue to grow in future and this will constitute a serious threat to the environment unless a decisive action is taken in term of applying the regulatory measures for achieving reduction in the global volume of aviation emission.

The impact of aviation emission or the consequences resulting from continuous excessive discharge of aviation emission on the global environment include are also found to include global warming and climate change, atmospheric pollution with adverse effect on air quality leading to asthma, bronchitis and other lung diseases. Prevalence of Aviation emission also lead to haze, fog and bad weather resulting in flight delays and cancellation and poor visibility for vehicles around the airports. It also causes atmospheric ozone depletion resulting in skin cancer and cataract. It further causes acid rain resulting in acidification of lakes and rivers leading to the killing of fishes of fishes and water lives.

As already discussed above that aviation emission is fast increasing in growth and that the increase has adverse impact on human lives and the global environment, it is hereby recommended that the UNFCCC convention, the Kyoto Protocol and the ICAO international Standards regulations introduced should be effectively applied and implemented by member states so as to achieve effective reduction in aviation emission globally.