Review on the Influence of Primary Air Pollutants upon Human Health

Garba Ibrahim Dakasku[1], Isa Sa'idu[2], Hassan Galadima Kurkushe[3]

[1]*Department of Preliminary Studies, Umar Suleiman College of Education Gashu'a, Yobe State, Nigeria.*
[2]*Department of Science Laboratory Technology, Umaru Ali Shinkafi Polytechnic Sokoto, Sokoto State, Nigeria.*
[3]*Department of physics, Umar Suleiman College of Education Gashu'a, Yobe State, Nigeria.*

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Abstract - *Air pollution currently poses a great health and environmental concerns, these pollutants increases continuously due to man-made activities. This paper therefore, review primary air pollutants, types of primary air pollutants, sources of these pollutants, effects on human health and possible legislative and technological measures on primary air pollutants.*

***Key Words*: Pollution, Pollutants, Human, Health, Environment,**

1.0 Introduction

Detrimental impacts of air pollution on health have been noticed for a very long period of time, although effective legislation has led to a gradual change in the nature of outdoor air pollutants in developed countries [3]. Combustion of raw fuels indoors, fossils fuels and other man-made activities produces large amounts of pollutants in the air which still remain challenging because of the trans-boundary nature of air pollutants and their potential deterioration of local air quality which eventually causes hazard to human health [1]. The polluted air causes severe effects on human health mostly respiratory and cardiovascular illness [2]. The term pollution is too difficult to define due to its broad dimension; despite these difficulties, pollution can be defined as the existence of energy or matter whose nature, extent and position pose unwanted effects to the humans, environment and the ecosystem [5]. Whereas contamination is the presence of any small unwanted substance or impurities (if present above certain level) may cause harm to humans or the environment, its effects depend largely on the type and nature/toxicity of the substance [6]. However, Air pollution is a type of environmental pollution that has become of great concern since the industrial revolution because of its impacts on the environment and humans health and therefore needs a coherent approach because of its trans-boundary nature [25]. Air pollution occurs when air in the environment becomes in contact with any chemical, biological or physical substance in an amount that changes the natural characteristics of the air in the atmosphere [27].

1.1 Sources of air Pollution in the Atmosphere

There are basically two main sources of air pollution: they are natural and man-made sources of air pollution, the latter is produced from natural activities such as volcanoes, dust storms, pollen and bush fires whereas the former (which is of great concerns because of their long term effects in the atmosphere) occur due to burning, vaporization and friction [15].

1.2 Types of Air Pollutants

The atmosphere is made up of multiple air pollutants which occur from both natural and artificial sources, they are classified into primary and secondary air pollutants [10]. They exist as solid particles, liquid precipitates and gaseous form like sulphur dioxide and ozone. Primary air pollutants can be regarded as any dangerous substance or gas released into the atmosphere which pose direct effects on the environment or humans health e.g. sulphur dioxides (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), particulate matter (PM), volatile organic compounds (VOCs), and lead (Pb) [8; 7]. However, secondary air pollutants are formed by reaction between primary air pollutants or water vapour in the presence of energy from the sun e.g. Ozone [10].

1.3 Characteristics and Sources of Primary Air Pollutants

1.3.1 Sulphur Dioxides (SO_2)

Sulphur dioxide is an acidic, colourless gas with sharp, choking smell. Chemically is a reducing agent because it gives out electrons or receives oxygen from a substance and has a boiling point of about -10^{o}C [20]. It can be found from natural source like volcanisms and artificial sources such as burning of biomass, burning of fossil fuels, volatile organic sulphur compounds, they can also be emitted from soils, oceans and vegetation [5; 14].

1.3.2 Carbon Monoxide (CO)

Carbon monoxide is a colourless, odourless, tasteless gas. They are chemically reactive at a temperature of about 90°C [5] formed as a result of incomplete burning of substance containing carbon [23]. It is the second most abundant inorganic carbon product after CO_2 in the atmosphere and plays a significant role in dissolved organic carbon cycling [16]. Some of its sources include the burning of organic matter, coke and tobacco smokers [13]. Other prevalent sources include mobile source such as exhaust fumes from cars, trucks and buses, off road sources like aero plane, boat, agricultural and constructions equipment as well as point sources like chemical plants, steel mills, manufacturing plants, power plants, and hazardous waste incinerators. Non-point sources such as heating and cooling units, fire places, gas stations and open burning of waste [18; 21].

1.3.3 Nitrogen Oxide (NO_X)

Nitrogen oxides are group of very reactive gases consist of nitrogen dioxide and nitric oxide [4; 22]. Majority of nitrogen oxides are odourless, colourless and non-flammable but nitrogen dioxide (NO_2) together with other particles form reddish-brown blanket above several cities [4]. The primary sources of NOx are mobile and static combustion sites, vehicles, electric generators, industries and domestic fuel uses [4; 24]. NOx is an originator in the production of ground level ozone along with volatile organic compounds [24]. In the UK, the major sources of NOX are power stations, industries and vehicles [4]. Road traffics contribute to long-term ground-level concentrations of NOx however in the UK Cities; the highest concentration of NOx is at kerbside and street within tall buildings due to poor dispersion. The limit value of nitrogen dioxide concentration set by the European Union is $40\mu g/m^3$ [4].

1.3.4 Particulate Matter (PM)

Particulate matter is a mixture of fine particles with diameter between 0.001-100µm collectively recognized as aerosols. They can be suspended in air for a very long period of time and travelled over a long distance; Particulates are of different sizes having varying effects depending on its size [9]. Mainly emitted from waste burning, coal burning plant, construction & demolition sites, coal burning in stove, open burning of waste materials, diesel generators, road side dust and road traffic [30]. PM can be classified into Ultra-fine particles whose diameter is less than 100µm they have short life time therefore there effects depend on the proximity of the source [28]. Whilst fine PM commonly known as $PM_{2.5}$ is particle with diameter less than 2.5 microns mainly emitted from combustion of automobile [33].

1.3.5 Lead (Pb)

Lead is a trace metal, non-biodegradable, accumulative in nature produced from steel industries, plastics & pigments manufacturing, contaminated soil, coal-fired boiler, furnace burning and lead gasoline [35; 32]. Other sources of lead include domestic dust, urban soil and highway dust [29; 37].

1.3.6 Volatile Organic Compounds (VOCs)

Volatile organic compounds can be defined as organic classes with a vapour pressure less than 760torr (101.3KPa) and greater than 1torr (0.13KPa) at 20°C, they can be emitted from sources such as vehicles, petrochemical companies, waste water treatment sites, landfill sites [11; 17]. Other natural sources include volcanoes, bush fire, natural vegetation and forest [12].

1.3.7 Radon Gas (Rn)

Radon gas is a colourless, odourless and tasteless radioactive gas that occurs naturally from radioactive decay of uranium in soils, rocks, water and has half-life of about four days [40]. It is chemically inert, naturally occurring radioactive gas [41]. They can be found in almost all type of soils, such as rocks, granite, brick, sand, cement and gypsum from which building materials are produced. Other sources include marble and ceramics for decorative use [45]. It can also be found indoors and outdoors in buildings of all type and hence recommended level is given to be 4pCi/L (picocuries per litre) or more due to its harmful nature [39].

2.0 Primary Air Pollutants and their Health Influence

2.1 The Health Influence of Sulphur Dioxide (SO_2)

According to [38] prolong exposure to SO_2 causes pre-mature death, worsen and causes respiratory sickness such as asthma, heart and lungs diseases including variety of health and environmental impacts. Similarly sulphur dioxide irritates the eyes, nose, throat and respiratory tracks. Exposure to SO_2 of about 1,000ppm for a short time can lead to death [20]. Moreover, SO_2

causes sensitivities among asthma patients, lead to severe constriction of the bronchi to asthmatic patients and persuade the development of asthma [34]. Furthermore, [47] stated that the effects of SO_2 on living organisms is multidimensional because SO_2 is not only dangerous to the respiratory organs but to the whole cardiopulmonary system. Studies by Health Protection Agency also added that SO_2 affects not only the respiratory system but can also cause nasopharynx and gottins, redness and blisters, lacrimation, frostbite and Blindness [49]. The highest allowable limit for sulphur dioxide is 75ppb 99% per hour per day for every three years averagely and not more than 0.5ppm annually for primary and secondary respectively [53].

2.2 The Health Influence of Carbon Monoxide (CO)

The presence of carbon monoxide in the atmosphere is essential for the normal function of the Earth's plants, animals and natural environment [46]. Research has revealed that children and infants are the most vulnerable to CO toxicities and poisoning due to their high metabolic rate, other nonspecific symptoms among which include severe headache, dizziness, vomiting, drowsiness however acute symptoms include irritability, coma, loss of consciousness and exposure to high concentrations of CO may damage the brain and cause death [42]. In addition, the harmfulness and severity of CO depend on the level and concentration of an individual exposure to it [52]. The maximum agreed limit set by National Ambient Air Quality Standard is 9ppm for eight hours averagely for primary level and 35ppm for one hour averagely for secondary level. These values therefore should not to be exceeded annually [60].

2.3 The Health Influence of Nitrogen Oxide (NO_x)

Prolong and continues exposure to NOx increase the risk and accelerate cardiovascular and respiratory diseases especially the low level of NOx that is mostly found near motor ways [58]. Nitrogen oxide help in the formation of acid rain which when in contact with skin causes irritation, skin cancer and lead to the formation of other toxic gases that may be harmful to humans health [48]. Long exposure to NOx causes burning spasms, inflammation in the throat, visual loss, formation of fluids in the lungs and low oxygen intake [48]. Considering the health effects related to NOx, the maximum allowable limit of NOx set by Environmental Protection Agency in 1971 was 0.053ppm averagely per annum which was later reviewed in January, 2010 and set to be 100ppb averagely per hour [59].

2.4 The Health Influence of Particulate Matter (PM)

According to [43] particulate matter are believed to have been responsible for the recent increase in premature deaths from 418,000 cases in 2001 to about 514,000 cases in 2011 in China including the increase in number of hospitalization due to cardiovascular diseases and poor visibilities. However, the severity and concerns on particulate matter depend on the time and nature of the particle. Particulate matter are responsible for a wide range of cardiovascular diseases and long term exposure to particulate matter like $PM_{2.5}$ and PM_{10} can result to lungs cancer and death [19; 41]. In order to achieve the lowest limit, World Health Organization gives 10μg/m^3 annual mean, 25μg/m^3 per 24-hour average for $PM_{2.5}$ and 20μg/m^3 annual mean, 50μg/m^3 24-hour mean for PM_{10} [41]. However, USEPA set out12μg/m^3 for primary $PM_{2.5}$ and 15μg/m^3 for secondary per year averagely over every three years as well as 35μg/m3 for primary and secondary per year at 98% averagely in every three years [39]. In addition, the maximum limit for PM_{10} is 150μg/m^3 for both primary and secondary per day and should not exceed one time annually for every three years [39].

2.5 The Health Influence of Lead (Pb)

Lead is a public health threat that is believed to bring disorder of the biosynthesis of haemoglobin and anaemia, high blood pressure, kidney and brain damage, miscarriages, delicate abortions, disruption of nervous systems, declined in fertility of men through sperm destruction, diminished learning abilities of children, behavioural disruptions of children, such as aggression, impulsive behaviour and hyperactivity [51; 61]. In addition, lead can cause poor muscle coordination, damage to the nervous system, hearing and sight injury [54]. However, lead effects in children varies; it includes damage to the brain and nervous system, behavioral mishaps, anemia, liver and kidney damage, hearing loss, hyperactivity, developmental delays in some cases death, the maximum standard limit for lead is 0.15μg/m^3 [39].

2.6 The Health Influence of Volatile Organic Compounds (VOCs)

VOCs especially NMVOCs are known to be carcinogenic and mutagenic in nature, they react in the atmosphere to form ground level ozone and organic aerosols which collectively increase the risk and severity of respiratory and cardiovascular diseases [55]. Other health effects of volatile organic compounds exposure include Eye, nose, and throat irritation, headaches, loss of consciousness/co-ordination, nausea and dizziness. They can also cause harm to liver, kidney, and central nervous system, the possibilities of VOCs to cause any health effect depend on toxicity, amount and length of exposure to it [56].

2.7 The Health Influence of Radon Gas (Rn)

Exposure to high level of radon gas via respiratory tracks is known to cause lung diseases whereas long-term exposure to these gases increases the chance of developing lung cancer. However, Radon gas can only cause cancer after several years of exposure [51]. Radon gas is believed to be responsible for about 2,900 lung cancer death in United State of America in 2005 [65]. According to World Health Organization, exposure to radon gas increase the risk of lung cancer however there is no known threshold at which radon gas exposure has risk [57].

3.0 Control of Air Pollution

The history of air pollution control can be traced back to the prohibition of the use of coal as fuel in 1273 due to its detrimental health impacts and the clean air act of 1956 following the London smog in 1952 [62]. But [26] the history of environmental policies can be traced when air and water pollution was documented in fourteenth century and a control of air pollution from industries was introduced in 1860,s which controls the release of harmful substance in the environment. In recent years, several other laws have been modified from the older ones to integrate other set of substance like the Environmental Protection Act of 1990 [26]. The controls of air pollution need a coherent approach because of trans-boundary nature of air pollution. There are basically to broad main control measures of air pollution; the legislative control and technological control measures [63].

3.1 Legislative Control of Air Pollution

A number of legislations have been formulated to control air pollution in the UK and the world as a whole among which is the National Emission Ceilings Directive 2001/81/EC which was endorsed among European Countries to control pollutants e.g. SO_2, NOx, NH_3 and VOCs. This legislation was formed to protect the environment and human health against the impacts of eutrophication, acidification and the formation of stratospheric ozone [31]. The Gothenburg Protocol (1999) to the United Nations Economic Commission for Europe's Convention on Trans-boundary Air Pollution (LRTAP) controls regional emissions of SO_2, NOx, NH_3 and VOCs in Europe by setting maximum allowable limits to these pollutants. The Geneva Protocol of 1991 which came into action in 1997 controls VOCs pollution. The protocol provided 30% VOCs emissions decrease across Europe as of 1999 [64]. The Vapour Recovery Directives regulate the emissions of VOCs from point source e.g. petrol terminals within Europe [50]. The Solvents Directive (1999/13/EC) considers VOCs emissions from various processes and installations e.g. printing, pharmaceutical corporations, surface cleaning and dries cleanings [50]. The Paint Directive regulates VOCs in paints, vehicle-refinishing products and vanishes [50]. Directive on Integrated Pollution Prevention and Control (96/61/EC) came into existence in 1999 regulates air, land and water pollution by industries within Europe [31]. The EU Directive 91/441/EC instructed the use of three-way catalysts in new petrol cars within Europe in order to reduce emissions of CO, VOCs, PM and NOx from road traffic [31]. The table below gives a summary of the maximum allowable limit for primary air pollutants especially from point sources e.g. industries provided by legislation in various time.

Table -1: Summary of primary pollutants and maximum limit of exposure per unit time

Pollutants	Maximum Limit	Time limit
Particulate matter $PM_{2.5}$	12µg/m³ for primary PM,	Yearly average for every three years.
	15µg/m³ for secondary PM	
	35µg/m³ for primary and secondary PM.	98% yearly average over three years.
PM_{10}	150µg/m³ for primary and secondary	Should not be exceeded once a year averagely for 3 years
Sulphur dioxide	75 ppb for primary SO_2	99% of an hour daily limit averagely over three years for primary and 0.5 should not be exceeded once in a year for secondary.
	0.5ppm for secondary SO_2	
Nitrogen oxide	100ppb or 200µg/m³	98% yearly average over three years.

VOCs	The limit for VOCs depends on its source e.g. for interior & ceiling painting should be <25% at a temperature of 60°C	
Lead	0.5µg/m³	Should not be exceed
Radon gas	4pCi/L	
Carbon monoxide	9 ppm 10µg/m³	Exposure should not exceed eight hours per year
	35ppm	Exposure should not exceed an hour per year

(39; 53; 36; 31 and 59)

3.2 Technological Control of Air Pollution

Air pollution from stationary sources such as steel mills, power plant, cement industries, refineries and other industrial processes release huge amounts of pollutants into the atmosphere in form of particles, gases or aerosols [66]. These pollutants can be control using air pollution control devices; these devices cleaned the exhaust fumes before release into the atmosphere. However, the selection of appropriate control device depend on type and nature of the pollutants, condition of the pollutants source and control efficiency needed [66]. The following are some commonly used air pollution control devices: Bag Houses, Scrubbers, Absorbers, Cyclones, Vapour Condensers, Electrostatic Precipitators and Catalytic Oxidizers [44]. The table below gives a brief summary of typical primary air pollution control device, the type of pollutants it controls and their area of application/usage.

Table 2: Pollutants, Pollution Control Device and Area of Application

Common Control Devices	Pollutants	Examples Where Used
Packed towers, spray chambers, venturi scrubbers	Gases, vapors, sulfur oxides, corrosive acidic or basic gas streams, solid particles, liquid droplets	Asphalt and concrete batch plants; coal-burning power plants; facilities that emit sulfur oxides, hydrogen sulfide, hydrogen chloride, ammonia, and other gases that can be absorbed into water and neutralized with the appropriate reagent
Carbon adsorbers	Vapor-phase volatile organic compounds (VOCs), hazardous air pollutants (HAPs)	Soil remediation facilities, oil refineries, steel mills, printers, wastewater treatment plants
Fabric filters or bag houses	Particulate matter (PM)	Asphalt batch plants, concrete batch kilns, steel mills, foundries, fertilizer plants, and other industrial processes
Catalytic reactors, catalysts	VOCs, gases	Landfills, oil refineries, printing or paint shops
Cyclones	Large PM	Woodworking shops, pharmaceutical manufacturers, cotton gins, rock crushers, cement plants
Electrostatic precipitators (ESPs)	PM	Power plants, steel and paper mills, smelters, cement plants, oil refineries
Incinerators, thermal oxidizers, afterburners	VOCs, gases, fumes, hazardous organics, odors, PM	Soil contaminated with gasoline, landfills, crematories, inks from graphic arts production and printing, can and coil plants, hazardous waste disposal
Biofilters	VOCs, odors, hydrogen sulfide (H_2S), mercaptans (organic sulfides)	Wastewater treatment plants, industrial processes

3. CONCLUSIONS

Several studies has proved beyond reasonable doubt that anthropogenic activities are the most common major sources of pollutants in the environment which is believed to have serious effects on human health as evident from the great smoke of London in 1952, other epidemiological studies as well as laboratory investigations indicate some of the health impacts associated with both short and long term exposure to some of this pollutants. The most renowned health effects are mostly cardiovascular and cancer, Despite series of legislative measures date back to 1845 to date as well as technological control measure available to control and reduces human impacts of these pollutants, their effects still remain persistent due to Trans boundary nature of air pollutants. The legislative and technological control measures lack coherent/comprehensive approach throughout the globe and the atmosphere has no boundary. Primary pollutant are considered to be the most harmful therefore often becomes the reason why environmental organizations across the world set limits especially for point source pollutants including various legislation set to reduce the impacts of this pollutants.

REFERENCES

[1] J Othman, M. Sahani, M. Mahmud and, M.K. Sheikh Ahmad "Trans-boundary smoke haze pollution in Malaysia: Inpatient health impacts and economic valuation" *Environmental Pollution*, **189**(0), 2014, Pp. 194-201.

[2] A.A.M. Torricelli , M. Matsuda, P. Novaes, A.L.F. Braga, P.H.N. Saldiva, M.R. Alves and M.L.R. Monteiro "Effects of Ambient Levels of Traffic-derived Air Pollution on the Ocular Surface: Analysis of symptoms, conjunctival goblet cell count and mucin 5AC gene expression". *Environmental research,* **131**(0), 2014, Pp. 59-63.

[3] S.L. Johnston and A.J. Chauhan "Air pollution and infection in respiratory illness" [online], 2003.

[4] United States Environmental Protection Agency "NOx; how nitrogen oxide affects the way we live and breathe" [online], 2003.

[5] F. R. Spellmanx "The science of environmental pollution. 2nd ed. Boca Raton, London, New York: Taylor and Francis. 2010.

[6] Environmental Protection Agency "Site contamination-what is site contamination" [online], 2009.

[7] R. T. Wright "Environmental Science toward a Sustainable Future" 9th ed. New Delhi: Prentice-Hall, 2005.

[8] J A. Bernstein, N. Alexis, H. Bachus, L. Bernstein, P. Fritz, E. Horner, N. Li, S. Mason, A. Nel, J. Oullette, K. Reijula, T. Reponen, J. Seltzer, A. Smith and S.M. Tarlo "The health effects of nonindustrial air pollution" *Journal of Allergy and Clinical Immunology*, 121(3), 2008, Pp.585-591.

[9] A. Przybysz, A. Saebo, H.M. Hanslin and S.W. Gawroński "Accumulation of particulate matter and trace elements on vegetation as affected by pollution level, rainfall and the passage of time" *Science of The Total Environment*, **481**(0), 2014 Pp. 360-369.

[10] D.D. Chiras "Environmental Science" 8th ed. London, United Kingdom: Johns & Barlett, 2009.

[11] C. Liu, W. Chen, C. Yuan and C. Lin "Multivariate analysis of effects of diurnal temperature and seasonal humidity variations by tropical savannah climate on the emissions of anthropogenic volatile organic compounds" *Science of The Total Environment,* **470–471**(0), 2014, Pp. 311-323.

[12] M. Prendez, V. Carvajal, K. Corada, J. Morales, F. Alarcon and H. Peralta "Biogenic volatile organic compounds from the urban forest of the Metropolitan Region, Chile" *Environmental Pollution* [online], **183**(0), 2013, Pp. 143-150.

[13] L. Rochette, Y. Cottin, M. Zeller and C. Vergely "Carbon monoxide: Mechanisms of action and potential clinical implications" *Pharmacology & therapeutics* [online], **137**(2), 2013, Pp. 133-152.

[14] B.C.T. Macdonald, O.T. Denmead, I. White and M.D. Melville "Natural sulphur dioxide emissions from sulphuric soils" *Atmospheric Environment* [online], **38**(10), 2004, Pp. 1473-1480.

[15] D. D. Chiras "Environmental Science" 9th ed. London, United Kingdom: Johns & Barlett, 2010.

[16] Y. Zhang and H. Xie "The sources and sinks of carbon monoxide in the St. Lawrence estuarine system" *Deep Sea Research Part II: Topical Studies in Oceanography* [online], **81–84**(0), 2012, Pp. 114-123.

[17] F. Tassi, F. Capecchiacci, L. Giannini, G.E. Vougioukalakis and O. Vaselli "Volatile Organic Compounds (VOCs) in air from Nisyros Island (Dodecanese Archipelago, Greece): Natural versus anthropogenic sources" *Environmental Pollution* [online], **180**(0), 2013), Pp. 111-121.

[18] Department of Health and Environmental Control "We promote and protect the health of the public and the environment [online], 2013.

[19] H.J. Jahn, A. Schneider, S. Breitner, R. Eibner, M. Wendisch and A. Kramer " Particulate matter pollution in the megacities of the Pearl River Delta, China – A systematic literature review and health risk assessment" *International journal of hygiene and environmental health* [online], **214**(4), 2011, Pp. 281-295.

[20] National Oceanic and Atmospheric Administration "Sulphur Dioxide" [Online], 2012.

[21] P.J. Parks and G.D. Hrunka "Creating a market for reduced carbon monoxide emissions from mobile sources" *Environmental Science & Policy* [online], **3**(1), 2000, Pp. 47-54.

[22] Department for Environment, Food and Rural Affairs "Air pollution in the UK" [online], 2010.

[23] Industrial Accident Prevention Association "Carbon monoxide in the work place" [online], 2008.

[24] M. Kampa and E. Castanas "Human health effects of air pollution" *Environmental Pollution*, 151, 2008, Pp.362-344.

[25] U. Alyuz and K. Alp "Emission inventory of primary air pollutants in 2010 from industrial processes in Turkey" *Science of The Total Environment* [online], (0), 2014.

[26] L. Holland and Y. Boon Foo "Differences in environmental reporting practices in the UK and the US: the legal and regulatory context" *The British Accounting Review*, 35(1), 2003, Pp. 1-18.

[27] World Health Organization "Air pollution and health" [online], 2014c.

[28] P. Pant and R.M. Harrison "Estimation of the contribution of road traffic emissions to particulate matter concentrations from field measurements" A review. *Atmospheric Environment*, **77**(0), 2013, Pp. 78-97.

[29] J. Yoshinaga, K. Yamasaki, A. Yonemura, Y. Ishibashi, T. Kaido, K. Mizuno, M. Takagi and A. Tanaka "Lead and other elements in house dust of Japanese residences – Source of lead and health risks due to metal exposure" *Environmental Pollution* [online], **189**(0), 2014, Pp. 223-228.

[30] R.S. Patil, R. Kumar, R. Menon, M.K. Shah and V. Sethi "Development of particulate matter speciation profiles for major sources in six cities in India" *Atmospheric Research,* **132–133**(0), 2013, Pp. 1-11.

[31] European Environment Agency "Air pollution-SOER 2010 thematic assessment" [online], 2010.

[32] N.S. Duzgoren-Aydi "Sources and characteristics of lead pollution in the urban environment of Guangzhou" *Science of The Total Environment* [online], **385**(1–3), 2007, Pp. 182-195.

[33] A.R. Maroko "Using air dispersion modelling and proximity analysis to assess chronic exposure to fine particulate matter and environmental justice in New York City" *Applied Geography*, **34**(0), 2012, Pp. 533-547.

[34] K. Kim, S.A. Jahan and E. Kabir "A review on human health perspective of air pollution with respect to allergies and asthma" *Environment international*, **59**(0), 2013, Pp. 41-52.

[35] J. Duan and J. Tan "Atmospheric heavy metals and Arsenic in China: Situation, sources and control policies" *Atmospheric Environment*, **74**(0), 2013, Pp. 93-101.

[36] Environmental Protection Agency "Secondary National Ambient Air Quality Standard for Oxides of nitrogen and sulphur; Final rule" [online], 2012.

[37] X. Hu, Y. Sun, Z. Ding, Y. Zhang, J. Wu, H. Lian and T. Wang "Lead contamination and transfer in urban environmental compartments analysed by lead levels and isotopic compositions" *Environmental Pollution*, **187**(0), 2014), Pp. 42-48.

[38] X. Pan "Sulfur Oxides: Sources, Exposures and Health Effects *in* Nriagu,J. O.(ed). *Encyclopaedia of Environmental Health.* Burlington: Elsevier, 2011.

[39] United State Environmental Protection Agency "National Ambient Air Quality S standard, air and radiation" online], 2012c.

[40] National Safety Council "Radon" [online], 2009.

[41] World Health Organization "ambient (outdoor) air quality" [online], 2014a.

[42] Paediatric Environmental Health Speciality Units "carbon monoxide poisoning in children: guidance for disaster events" [online], 2013.

[43] Z. Cheng, J. Jiang, O. Fajardo, S. Wang and J. Hao "Characteristics and health impacts of particulate matter pollution in China (2001–2011)" *Atmospheric Environment*, **65**(0), 2013, Pp. 186-194.

[44] Department of Natural Resources "How air pollution is controlled" [online], 2012.

[45] A.F. Saad, H.H. Al-Awami and N.A. Hussein "Radon exhalation from building materials used in Libya" *Radiation Physics and Chemistry*, (0), 2014.

[46] J.A. Raub "Health effects of exposure to ambient carbon monoxide" *Chemosphere - Global Change Science,* **1**(1–3), 1999, Pp. 331-351.

[47] Z. Meng, G. Qin, B. Zhang, H. Geng, Q. Bai, W. Bai and C. Liu "Oxidative damage of sulphur dioxide inhalation on lungs and hearts of mice" *Environmental research,* **93**(3), 2003, Pp. 285-292.

[48] Agency for Toxic Substance and Disease Registry "ToxFAQs for nitrogen Oxide" 2002.

[49] Health Protection Agency "Sulphur dioxide incident management" [online], 2010.

[50] European Commission "Environment" [online], 2014.

[51] Lenntech "Chemical properties of lead-health effects of lead-environmental effects of lead" [online], 2014.

[52] G. Lippi, G. Rastelli T. Meschi, L. Borghi and G. Cervellin "Pathophysiology, clinics, diagnosis and treatment of heart involvement in carbon monoxide poisoning" *Clinical biochemistry,* **45**(16–17), 2012, Pp. 1278-1285.

[53] United State Environmental Protection Agency "Sulphur dioxide" [online], 2014.

[54] United State Environmental Protection Agency "Human Health and Lead" [online], 2013a.

[55] A. Laurent and M.Z. Hauschild "Impacts of NMVOC emissions on human health in European countries for 2000–2010: Use of sector-specific substance profiles" *Atmospheric Environment*, **85**(0), 2014, Pp. 247-255.

[56] United State Environmental Protection Agency "An Introduction to Indoor Air Quality (IAQ) Volatile Organic Compounds (VOCs)" [online], 2012a.

[57] World Health Organization "Ionizing radiation: Radon" [online], 2014b.

[58] Y.J. Wang, A. DenBleyker, E. McDonald-Buller, D. Allen and K.M. Zhang "Modelling the chemical evolution of nitrogen oxides near roadways" *Atmospheric Environment,* **45**(1), 2011, Pp. 43-52.

[59] United State Environmental Protection Agency "Nitrogen dioxide" [online], 2013b.

[60] United State Environmental Protection Agency "Carbon monoxide" [online], 2012b.

[61] A. Garcia-Alix, F.J. Jimenez-Espejo, J.A. Lozano, J G. imenez-Moreno, F. Martinez-Ruiz, L. Garcia Sanjuan, G. Aranda Jimenez, E. Garcia Alfonso, G. Ruiz-Puertas and R.S. Anderson "Anthropogenic impact and lead pollution throughout the Holocene in Southern Iberi". *Science of the Total Environment*, **449**(0), 2013, Pp. 451-460.

[62] H.C Routledge and J.G. Ayres "Air pollution and the heart" *Occupational medicine*, 55(0), 2005, Pp. 439-447.

[63] United Nations Economic Commission for Europe "Air pollution" [online], 2014.

[64] European Environment Agency "Energy and environment report" [online], 2008.

[65] United State Environmental Protection Agency "Why is radon the public health risk that it is" 2013d.

[66] Air and Waste Management Association: Fact Sheet "Air pollution emissions control devices for stationary sources" 2007.