International Research Journal of Environment Sciences ISSN 2319–1414
Vol. 4(9), 63-68, September (2015) Int. Res. J. Environment Sci.

Review Paper

A review of some Specific Air Pollutants and its exposure related to Human Health

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Available online at: www.isca.in, www.isca.me
Received 6th June 2015, revised 12th July 2015, accepted 24th August 2015

Abstract

Air pollution is one of the extremely serious problem now a day, primarily due to development of many metropolitan cities. A large number of urban areas and growing industries resulted air pollution threats ranging from local to global. Recent year have seen an increasing number of air pollution exposure studies by different researcher. In this article, air pollutant and its health impact studies carried out in many countries are reviewed extensively. These pollutant sources includes power plants, industrial units, vehicular traffic, biomass burning, which generate particulate matter (PM_{10} and $PM_{2.5}$), Sulphur dioxide (SO_2), oxides of nitrogen (NOx), carbon monoxide (CO), ammonia (NH_3), ozone (O_3), Volatile organic compounds (VOCs), Polycyclic aromatic hydrocarbons (PAHs) etc. The present review deals with the major air pollutants and their impacts on human health. This paper provides easily understandable and useable information to the general people especially to the people affected by the air pollutants in particular.

Keywords: Air Pollution, gaseous pollutants, human health and toxicity.

Introduction

At the earlier stage of air pollution was not considered as a global problem but after the industrial revolution with uncontrolled use of fossil fuels resulted the air pollution a serious topic of interest. The air pollution is continuously increasing day by day with over exploitation of natural fuel resources, rapid urbanization, industrialization, rapid economic development[1]. The Common air pollutants which draw intense concerns for health hazards include fine particulate matters (PM_{10} and $PM_{2.5}$), Sulphur dioxide (SO_2), oxides of nitrogen (NOx), carbon monoxide (CO), ammonia (NH_3) and ozone (O_3).These pollutants having their inherent properties of emission, reaction, chemical composition and ability to defuse long or short distance, crosses all geographical boundaries. Air pollution may cause acute and chronic disease symptoms in human by either inhalation or ingestion. The several reports and research published on Human health affected due to air pollution by different researcher and scientist. They reported a wide range of adverse health impact related to air pollution, such as chronic respiratory, cardiovascular disease and premature mortality[2]. The common adverse effect of Air pollutants are asthma, chronic obstructive pulmonary disease and it may also increase the risk of heart attack, lung cancer, stroke, cardiac arrhythmia etc. Short-term but severe air pollution exposure causes emergency visits to clinics and hospital admissions[3].

Here in this article we have thoroughly discussed about the contemporary research studies outcome on the air pollution exposure to various human health problems in our day to day real situations. Some suggestions about the research gaps and future prospects are proposed at last.

Description of pollutants and its Impacts

Different air pollutants such as particulate matter (PM_{10} and $PM_{2.5}$), Sulphur dioxide (SO_2), oxides of nitrogen (NOx), carbon monoxide (CO), ammonia (NH_3) and ozone (O_3) enter in human body primarily via inhalation, ingestion and dermal contact[2]. The past decade studies shows increase in mortality and morbidity rate related to air pollution exposure worldwide. The compositions of air pollutants are responsible for a large number of acute and chronic health problems ranging from irritation to even cancer. Various types of studies has been conducted to ascertain air pollutants effects on health by epidemiology, and controlled human exposure studies, molecular and cell biology[4]. Short term exposure to air pollution in sensitive population (children, elderly) are associated with exacerbation of acute and chronic respiratory conditions, asthma outcome, emergency hospital visits, and hospital admission throughout the world. As per WHO survey, the air pollution play vital role in premature death and lost life annually, approximately 800,000 and 4.6 million repectively[5].

Particulate Matter (PM) is the complex mixer of particulates like aerosol, dirt's, and liquid droplets which vary in size and are produced by both natural and anthropogenic activities. After the industrial revolution Particulates increases in the atmosphere and play vital role on climate change and health related exposure confirmed by several reseachers[6]. Motor vehicle exhaust, thermal power plants emissions, biomass burning emissions etc. resulted harmful levels of fine particles in the air[7]. Particulate matters measured as suspended particles (SPM), fine particulates PM_{10}(<10μm), $PM_{2.5}$(<2.5μm)[8]. The serval researcher also concluded the mixture of particulates play as a condensation nuclei and form cloud droplets (mixer of liquid and solid particles), reflecting cloud and precipitation formation and causing indirect radioactive forcing of climate change[9]. The Several research confined that the chemical properties of particulates depend upon characteristic of atmospheric composition such as aerosol acidity, aerosol hygroscopicity, water-soluble ions, soil dust etc)[10]. In the atmosphere PM may play great role as a reservoir species for many pollutants ranging from metal compounds to acid droplets[11].

Health impacts (mortality, morbidity) due to air pollution exposure can be viewed in respect of economic loss. 1.35% of the total GDP loss was found in 2006 from acute and chronic health effects on human body by access exposure of particulate pollution in china. The most (>95%) indicative loss was from premature death, chronic respiratory disease[12].

Particulate mattercontains a large number of mutagenic, genotoxic and carcinogenic species. Particulate matter has been linked to premature death, lung cancer, pulmonary and cardiovascular health problems[13]. Many researcher from different world especially experts of physiological and toxicological scientist has suggested that the particulate (Fine particulates) which harbors ionics (sulfates, nitrates), trace metals (Pb, Cd) may play the vital role to acute and chronic effects on different part of human bodies, sometimes seriously in synergistically. The inhalable particles that penetrates deep in the lung especially fine particulates with a less than or equal to a 10 μm diametere[14]. As per WHO report particulate air pollution is one of the great cause of premature mortality. PM is the 13th leading cause of premature death globally[5].

Sulphur dioxide is a primary air pollutant gas with acute smell and an irritating agent. The main sources of Sulphur dioxide are volcanoes and from various industrial process[15]. Combustion of the fossil fuels (coal, petroleum) containing Sulphur releases Sulphur dioxide in the atmosphere. In the atmosphere Sulphur dioxide oxidize in the presence of OHradicals and create new compound that is sulphuric acid (H_2SO_4)[16]. It is very hydrophilic in nature and due rapid condensation of Sulphur dioxideform aerosols with many chemical composition when pH below 5.0 level[17,18]. The emission of Sulphur dioxide about 100 Metric tons per year (Mt/yr-1) through coal and industries which is about 70% of all Sulphur emissions. Apart from that Sulphur emanating from oceanic plankton about 13 to 36 (Mt/yr-1), from volcanoes 6 to 20 (Mt/yr-1), from biomass burning 1 to 6 (Mt/yr-1), and land biota and soils 0.4 to 5.6 (Mt/yr-1)[19].

In South China critical loads of SO_2 was carried out to dry deposition in the city[20]. The average critical loads of SO_2 dry deposition (1.15 gSm−2 yr−1) was less than the regulatory standard, some site had excess critical loads of SO_2 dry deposition (1.0 gSm−2 yr−1) that exceed the regulatory standard that may damage to natural ecosystems and crops, as well as having health effects on local and regional scale, even supposed to be the more likely cause than acid deposition for the dieback of the Masson pine trees in some areas of South China[21].

The several epidemiological studies from different part of world has declare the Sulfur as an independent risk for mortality[22]. Epidemiological studies have been found that the short-term exposure of sulphur dioxide can effect respiratory health and pulmonary function of the health of children. Especially those children who have been asthmatic problem, the effect of SO_2 on pulmonary function was greater as compare to children without asthma[23] because of highly solubility with water. Resulted the most of the inhaled SO_2 is absorbed during the nasal breathing. Sulfur dioxide can also enter the blood stream in the form of sulfur and combines with the globulins[15]. The main metabolite produced sodium sulphite in the blood after respiratory exposure to SO_2. This metabolite causes depression in synthesis of DNA and induces chromosomal aberrations in human lymphocytes[24].

NOx is combined mixture of two gaseous compounds i.e. nitric oxide (NO) and nitrogen dioxide (NO_2). The production of oxides of nitrogen in the atmosphere due to reaction between nitrogen and oxygen gases at high temperature during combustion[25]. The production of NOx components mainly through the emission from natural (biomass burning) and anthropogenic sources (transport, industries, power plants). In the atmosphere due to presence of conversing Nox components, they form photo chemical oxidant and nitrogenous species such as Peroxy Acetyl Nitrate (PAN) with OH^+ within the troposphere[26].

In the Europe the short term effect of nitrogen dioxide was carried out to cardiovascular and respiratory mortality rate in thirty (30) European cities[27]. The studies was indicated the nitrogen dioxide strongly effect on cardiovascular system and also great impact on respiratory mortality rate. The observation of cardiovascular mortality was investigated mainly in western and southern European cities due to higher consumption NO_2 by large number of household. The authors were indicated about the respiratory mortality rate after the average exposure of nitrogen dioxide over 2 days. The results were showing the exposure of nitrogen dioxide was impacted about 45% for respiratory mortality and 22% for cardiovascular mortality.

Nitrogen dioxide (NO_2), form nitrogen free radical in the atmosphere. It is very highly reactive and irritable in nature as well as water-soluble gas, due to this it can easily deposited in the lungs. NO_2 reacts in the atmosphere with aerosols and catalyst in the troposphere to form smog (photochemical oxidant) which is more dangerous and health threat because it can absorb entire respiratory tract[27]. The access level of nitrogen dioxide in the lower atmosphere, it can be very dangerous to decrease lung capacity (lung injuries, suffocation, breathing problems) and may affect the defensive mechanisms of pulmonary function[28]. NO_2 an oxidant gas**,** so it is very dangerous to asthmatic patient that's why NO_2considered to be potential risk factor for Asthma[29]. It can serve effect on pulmonary edema and damages central nervous system, tissue[30].

Ammonia (NH_3) is one of the reduced forms of reactive nitrogen (N_r) and third most abundant N compound which have great role in the atmosphere because of its direct contribution to secondary photo- or smog reactions of air pollutants. It affects the various components of the environment viz. air, water, soil and ecology[31]. The sources of ambient NH_3 are various natural and anthropogenic sources. Natural sources include forest fires, losses from soil under natural vegetation. Anthropogenic sources of ambient NH_3 are the uses of nitrogenous fertilizers in agricultural practices, livestock establishments, industries, landfills, biomass burning and vehicular emissions[32]. NH_3have properties to neutralize atmospheric acids (H_2SO_4 and HNO_3) which is secondary product of the photo-oxidation of SO_2 and NOx emissions that why NH_3 is an important trace gas in the troposphere[33]. The recent emphasis for the estimation of ammonia emission worldwide is due to its potential for globalclimate change based on its ability to form fine particulates ($PM_{2.5}$) like ammonium sulphate, ammonium nitrate and ammonium chlorides[34]. The average global concentration of atmospheric ammonia ranges from 1 to 10 µg $NH_3 \cdot m^{-3}$of air[35].

In the current era the global NH_3 emissions is more than doubled as compare to pre-industrial times due to over intensification of agricultural and access use of chemical fertilizer in the agriculture field[36]. It is highly ecological sensitive and significance due to leading large uncertainties in the magnitude of ammonia emissions. But due to lake of mainly ground-based observations and a virtual absence of atmospheric measurements, it may get highly concern to the researchers[37-40]. The largest producer of Atmospheric NH_3 is cattle waste about 39% of total emission of ammonia. The nature also produce ammonia about 19% i.e. second largest producer of ammonia and other hand about 17% from NH_3-based fertilizers, 13% from biomass burning, 7% from crops and 5% emissions from humans, pets and waste water respectively. The current research and evidence indicated that population and traffic pollution, the ambient level of ammonia level is higher than agriculture field. Due to levels of ammonia found higher in more densely populated areas. So it may have a capacity to greater impact in the non-agricultural regions in coming future[41].

China is a major contributor of NH3emission which is 2 to 3 times greater than the European and US emissions over the period of 1990 to 2005[42-46]. The several research and scientific investigation have been done in china for NH_3 emission. The result was showed that the major contributor of NH_3 emissions in China from agriculture which was about 80 % of total emission. Apart from that 30% to 60% NH_3 emission from livestock and 17% to 47% from nitrogenous fertilizers followed by 20% for energy, 2.5% for human beings and 1% for poultry[43-49].

When the level of NH_3 in the air higher than 50 ppm its act like an irritating agent with very strong odor. If access level of ammonia inters our bodies through inhalation, it can be inter in the different part of body system and form ammonium compounds that may spread throughout the body in seconds[50]. The exposure of ammonia can irritate the respiratory tract and eyes, even at low level[51]. Ammonia have hygroscopic characteristic, it can easily deposit on upper respiratory track and can reduce lung function. At high concentration of ammonia increase incidence of chronic cough, wheezing, shortness, organic dust toxin syndrome, hyperactive airway diseases, chronic fatigue, asthma, bronchitis, air way obstruction and irritation of eye[52].

Carbon monoxide (CO) is slightly lighter than air and it is colorless, odorless, and tasteless gas. The atmospheric CO produced from combustion of fossil fuel, oxidation of methane and non-methane hydrocarbons and from partial oxidation of carbon-containing compounds[53]. The atmospheric lifetime of CO depending on the season, it can vary between two weeks to three months[54]. Ocean is a the largest source of Carbon Monoxide, due to presence of different type of algae that produce CO through photochemical reactions in the open sea with the chromophoric dissolved organic matter, that contribute atmospheric CO 1000+200 Tg per year[55]. The atmospheric CO load is mostly generating by interaction of solar radiation with methane i.e. 50% of the total natural production[56].

The studies of cardiovascular mortality due to short-term effects of carbon monoxide pollution were carried out in 19 European cities[57]. The authors found that the CO was significantly associated with cardiovascular mortality because the total death of analyzed cities about 45%, related to cardiovascular mortality. The mortality of cardiovascular due to the effect of CO pollution was observed mainly in two cities that is western and southern European cities. The effect of total and cardiovascular mortality was larger in both cities when the standardized mortality rate was lower.

In the present scenario due to rapid increasing of CO level in atmosphere, it is recognized as an environmental pollutant with several adverse effects on health[55]. After the inhalation of CO, inter in the blood stream and binds rapidly with hemoglobin (Hb) and form carboxyhemoglobin (COHb). The carrying capacity of oxygen in the blood decreases, resulting deficiency of hemoglobin in the body occur that is called tissue hypoxia. The affinity of CO for hemoglobin is 210 times greater as compare to O_2 affinity for hemoglobin that means CO can easily displaces oxygen from hemoglobin[58].

Ozone is a secondary air pollutant with constituting of three oxygen atoms and three atomic molecules. It is an important substance that is currently very much in the news because of its role in the troposphere, where it is a pollutant. O_3 is a compound which forms at troposphere due to hydrocarbon and nitrogen oxide in the process photochemical oxidation. Hydroxyl radical (OH) is a main source for production of Ozone in troposphere because its reacts rapidly with various air pollutants and trace species which is found in the atmosphere[59,60]. O_3 is most dangerous air pollutant which created problems throughout world because of highly reactive in nature. It can adversely impacts on human bodies and ecological biodiversity, and is very difficult to control[61].

The Ozone pollution related impact on health and economic losses at global level for future aspect (2050) was carried out by using EPPA-HE model[62]. The studies indicated that the ozone concentration may change in lower and upper atmosphere in 2050 due climate and changes emission. The studies showing the possible impact of O_3 in future may increase, approximately 817000 additional mortalities rate increased which is 95% probability interval of 350000 to 2300000 peoples and economic losses of approximately 120 billion which is under95% range of 13 billion to 190 billion.

Ozone (O_3) is one of the most toxic oxidant which causes several effects on human health. Inhaled O_3 interact with lung surface at interface of epithelial lining fluid (ELF) which contains of surfactant and antioxidants. These oxidant mix with antioxidants or biomolecules which is present in the lung surface, resulting the biomolecules inactivation occur and form more reactive agents[63]. These reactive agents may harm epithelial damage, inflammatory response etc[64].

Conclusion

The present studies showing the exposure of air pollutant and epidemiologic studies are required in the current scenario. Increasing exposure data of air pollutants will provide scientific basis for characterization and health impact in the local environment. The many investigations have been reported, in the current scenario the air pollutants are increasing in numbers and have capacity to adverse impact at great extent level. This study indicating that air pollution is a trans–boundary pollutants that can impact at global scale and the problem may reached threatening dimensions after some years. But a scientist which is belongs to different countries who can share technical resource and communication for developed good and safer environment.

References

1. Rai R., Rajput M., Agrawal M. and Agrawal S.B., Gaseous air pollutants: a review on current and future trends of emissions and impact on agriculture, *J. Sci. Res. B.H.U.,* 77 **(102)** 477-483 **(2011)**

2. Kampa M. and Castanas E., Human health effects of air pollution, *J. Env. Pollut.,* **(151)** 362-367 **(2007)**

3. Hogg J.C., Chu F., Utokaparch S., Woods R., Elliott W.M., Buzatu L., Cherniack R.M., Rogers R.M., Frank C. Sciurba., Coxson H.O. and Pare P.D., The nature of small-airway obstruction in chronic obstructive pulmonary disease, *N. Engl. J. Med.,* **(350)** 2645-2653 **(2004)**

4. Folinsbee J.L., Human health effects of air pollution, *J. env. Hea. Presp.,* **(100)** 45-56 **(1992)**

5. World Health Organization, World Health Report, Reducing Risk, Promoting Healthy Life, World Health Organization, Geneva, Switzerland, Available from www.who.int/whr/2002/en/, **(2002)**

6. Yongjie Y., Yuesi W., Weiwe H., Bo H., Tianxue W. and Yanan Z., Size Distributions and Elemental Compositions of Particulate Matter on Clear, Hazy and Foggy days in Beijing, China, *J. Adv. Atmos. Sci.,* **27(3)** 663–675 **(2010)**

7. Kenney P.L., Gichuru M.G., Volavka-Close N., Ngo N., Ndiba P.K., Law A., Gachanja A., Gaita S.M., Chillrud S.N. and Sclar E., Traffic impacts on PM2.5 air quality in Nairobi, Kenya, *J. env. sci.,* **(14),** 369–378 **(2011)**

8. Xie P., Liu X., Liu Z., Li T., Zhon L. and Xiang Y., Human Health Impact of Exposure to Airborne Particulate Matter in Pearl River Delta, China, *J. Water. Air. Soil. Pollut.,* **(215)** 349–363 **(2011)**

9. IPCC, Climate Change, The Scientific Basis. Houghton et al., Eds., Cambridge University Press, Cambridge, UK, and New York, USA, 881 **(2001)**

10. Jun T., Tiantao C., Renjian Z., Junji C., Lihua Z., Qiyuan W., Lei L. and Leiming Z., Chemical Composition of $PM_{2.5}$ at an Urban Site of Chengdu in Southwestern China, *J. Adv. Atmos. Sci.,* **30(4),** 1070–1084 **(2013)**

11. Mouli P.C., Mohan S.V. and Reddy S.J., Chemical Composition of Atmospheric Aerosol (Pm_{10}) at a Semi-Arid Urban Site: Influence of Terrestrial Sources, *J. Env. Monitor. Asses.,* **(117)** 291–305 **(2006)**

12. Huang D., Xu J. and Zhang S., Valuing the health risk of particulate air pollution in the pearl River delta, China, *J. Env. Sci. Poli.,* **(15)** 38-47 **(2012)**

13. ElAssouli M.S., Airborne particulate matter (PM_{10}) composition and its genotoxicity at two pilgrimage sites in Makkah, Saudi Arabia, *J. Env. Chem. Ecotox.,* **3(4),** 93-102 **(2010)**

14. Pope III C.A. and Dockery D.W., Health Effects of Fine Particulate Air Pollution: Lines that Connect, Air and Waste Manage, *Assoc.,* **(56)** 709–742 **(2006)**

15. Petruzzi S., Musi B. and Bignami G., Acute and chronic sulfur dioxide (SO_2) exposure: an overview of its effects on humans and laboratory animals, *Ann. Ist. Super.*

Sanita., **30(2)** 151-156 **(1994)**

16. Yousefirad M. and Noroozpour H., Identification of the Gaseous Zone Origins in Talkhab Area, Markazi Province, Iran, *J. Amer. Sci.,* **7(4)** 179-180 **(2011)**

17. Singh B.H., Composition, Chemistry and Climate of the Atmosphere. A division of international publishing inc (Van Nostrand Reinhold) ISBN 0-442-01364-0, **(1995)**

18. Rattigan O.V., Dutkiewicz A.V., Das Mita., Judd C.D. and Husain L., Oxidation of SO_2 in Clouds at White face Mountain, *J. Water. Air. Soil. Pollut.,* 391–400 **(2001)**

19. Penner J.E., Andreae M., Annegarn H., Barrie L., Feichter J., Hegg D., Jayaraman A., Leaitch R., Murphy D., Nganga J., and Pitari G., Aerosols, their direct and indirect effects. www.ipcc.ch/pub/tar/wg1/160.htm, In: Climate Change: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881 **(2001)**

20. Tao F and Feng Z., Critical loads of SO2 dry deposition and their exceedance in south china, *J. Water. Air. Soil. Pollu.,* **(124)** 429–438 **(2000)**

21. Shen J., Zhao Q., Tang H., Zhang F., Feng Z., Okita T., Ogura N. and Totsuka T., Water, Air, and Soil Pollut. **(85)** 1299 **(1995)**

22. Pope III C.A., Burnett T.B., Thun M.J., Calle E.E., Krewski D., Ito k. and Thruston G.D., Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure t Fine Particulate Matter Air Pollution, *Amer. Med. Assoc.,* **(9)** 287 **(2002)**

23. Aekplakorn W., Loomis D., Vichit-Vadakan N., Shy C., Wongtim S. and Vitayanon P., Acute effect of sulphur dioxide from a power plant on pulmonary function of children, Thailand, *Int. j. Epid.,* **(32),** 854–86 **(2003)**

24. Yadav J.S. and Kaushik V.K., Effect of Sulfur Dioxide Exposure on Human Chromosomes, *Mut. Res.,* **(35)** 25-29 **(1996)**

25. Arthisree S.R., Sirisha D. and Gandhi N., Adsorption of Aqueous solution of NO_2 by neem bark dust, *Int. J. Chem. Tech. Res.,* **(5),** 550-555 **(2013)**

26. Gupta A., Kumar R., Maharaj K.K. and Srivastava S.S., Measurment of NO_2, HNO_3, NH_3 and SO_2 and related particulate matter at a rural site in Rampur, *India, J. Atmos. Env.,* **(37),** 4837-4846 **(2003)**

27. Samoli E., Aga E., Touloumi G., Nisiotis K., Forsberg B., Lefranc A., Pekkanen J., Wojtyniak B., Schindler C., Niciu E., Brunstein R., Fikfak M.D., Schwartz J. and Katsouyanni K., Short-term effects of nitrogen dioxide on mortality: an analysis within the APHEA project, *Eur. Respir. J.,* **(27)** 1129–1137 **(2006)**

28. Garrett M.H., Hooper M.A., Hooper B.M. and Abramson M.J., Respiratory symptoms in children and indoor exposure to nitrogen dioxide and gas stoves, *Am. J. Respir. Crit. Care. Med.,* **(158),** 891–895 **(1998)**

29. Shima M. and Adachi M., Effect of outdoor and indoor nitrogen oxide on respiratory system in school children, *Int. J. Epidemiol.,* **(29)** 862-870 **(2000)**

30. Lal S. and Patil S.R., Monitoring Of Atmospheric Behaviour of Nox From Vehicular Traffic, *Env. Monit. Assess.,* **(68)** 37–50 **(2001)**

31. Hsieh L.T. and Chen T., Characteristics of ambient ammonia levels measured in three different industrial parks in southern Taiwan, *Aero. Air. Qua. Res.,* **(10),** 596–608 **(2010)**

32. Sharma S.K., Saxena M., Mandal T.K., Ahammed Y.N., Pathak H., Datta A., Saud T. and Arya B.C., Variations in Mixing Ratios of Ambient Ammonia, Nitric Oxide and Nitrogen Dioxide in Different Environments of India, *J. Earth. Sci. Climat. Change.,* **(1)** 1-5 **(2010)**

33. Olszyna K.J., Bairai S.T. and Tanner R.L., Effect of ambient NH_3 levels on $PM_{2.5}$ composition in the Great Smoky Mountains National Park, *J. Atmos. Env.,* **(39)** 4593–4606 **(2005)**

34. Ianniello A., Spataro F., Esposito G., Allegrini I., Rantica E., Ancora M.P., Hu M. and Zhu T., Occurrence of gas Phase Ammonia in the Area of Beijing (China), *Atmos. Chem. Phys.,* **(10)** 9487–9503 **(2010)**

35. Mroczkowski W. and Stuczyñski T., Toxic Effects of Ammonia Volatilizing from Sandy Soil Fertilized with Ammonium Salts and Urea on Barley Crop Decreases, *J. Env. Stud.,* **(15)** 827-832 **(2006)**

36. Galloway J.N., Aber J.D., Erisman J.W., Sietzinger S.P., Howarth R.W., Cowling E.B. and Cosby B.J., The Nitrogen Cascade, *Biosciences*, **(53)** 341-353 **(2003)**

37. Asman W.A.H., Sutton M.A. and Schjoerring J.K., Ammonia: emission, atmospheric transport and deposition, *New Phytologist*, **(139)** 27-48 **(1998)**

38. Bouwman A.F., Lee D.S., Asman W.A.H., Dentener F.J., Hoek V.D.K.W. and Oliver J.G.J., A global high resolution emission inventory for ammonia, *Glob. Biogeochem. Cy*, **(11)** 561-587 **(1997)**

39. Dentener F.J. and Crutzen P.J., A three-dimensional model of global ammonia cycle, *Journal of Atmospheric Chemistry*, **(19)** 331–369 **(1994)**

40. Galloway J.N., Townsend A.R., Erisman J.W., Bekunda M., Cai Z., Freny J.R., Martinelli L.A., Sietzinger S.P. and Sutton M.A., Transformation of the Nitrogen Cycle: Recent trends, questions and potential solutions, *Science*, **(320)** 889-892 **(2008)**

41. Suh H.H., Allen G.A., Koutrakis P. and Burton R.M., Spatial Variation in acidic sulphate and ammonia concentrations within metropolitan Philadelphia, *Journal of Air and Waste Management Association*, **(45)** 442–452 **(1995)**

42. Klimont Z., Current and future emissions of ammonia in China, 10th International Emissions Inventory Conference: One Atmosphere, One Inventory, Many challenges, US EPA, 1-3 May, Denver, USA (**2001**)

43. Zhao D. and Wang A., Estimation of anthropogenic ammonia emissions in Asia, *Atmos. Environ,* **(28)** 687-694 **(1994)**

44. EMEP, webdab emission data hosted by the centre on emission inventories and projections (CEIP): http://www.ceip.at/, access: 20 may **(2015)**

45. USEPA, National Emission Inventory Tier Summaries: http://www.epa.gov/ttn/cheif/eiinformation.html, access: 14 may **(2015)**

46. Reis S., Pinder R.W., Zhang M., Lijie G. and Sutton M.A., Reactive nitrogen in atmospheric emission inventories, *Atmos. Chem. Phys*, **(9)** 7657-7677 **(2009)**

47. Oliver J.G.J., Bouwman A.F., Van der Hoek K.W. and Berdowski J.J.M., Global air emission inventories for anthropogenic sources of NOx, NH_3 and N_2O in 1990, *Environ. Polut.,* **(102)** 135-148 **(1998)**

48. Streets D.G., Bond T.C., Charmichael G.R., Fernandes S.D., Fu Q and He D., An inventory of gaseous and primary aerosol emissions in Asia in the year 2000, *J. Geophys. Res,* 108 **(20)** **(2003)**

49. He C.E., Liu X., Fangmeire A. and Zhang F., Quantifying the total airborne Nitrogen input into the agroecosystems in the North China Plain, *Agr. Ecosyst. Environ,* **(121),** 395-400 **(2007)**

50. Agency for Toxic Substances and Disease Registry (ATSDR), Toxicological profile for Ammonia, Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, **(2004)**

51. Holness D., Purdham T. and Nethercott J., Acute and chronic respiratory effects of occupational exposure to ammonia, *J. Am. Ind. Hyg. Assoc.,* **50(12),** 646-650 **(1989)**

52. Dewey E.C., Cox B. and Leyenaar J., Measuring ammonia concentration in barn using the draeger™ and pHydrion™ tests, *J. Swine. Hel. Prod.,* **(3),** 127-131 **(2000)**

53. Clerbaux C., Edwards P.D., Deeter M., Emmons L., Lamarque J., Tie X.X., Massie T.S. and Gille J., Carbon monoxide pollution from cities and urban areas observed by the Terra/MOPITT mission, *Geophy. Res. Let.,* **(35),** **(2008)**

54. Fokeeva E.V., Safronov A.N., Rakitin V.S., Yurganov L.N., Grechko E.I. and Shumskii R.A., Investigation of the 2010 July–August Fires Impact on Carbon Monoxide Atmospheric Pollution in Moscow and Its Outskirts, Estimating of Emissions, *J. Atmos. Oce. Phy.,* 6 **(47),** 682–698 **(2011)**

55. Asatar G.I. and Nair P.R., Spatial distribution of near-surface CO over Bay of Bengal during winter: Role of transport, *J. Atmos. Solar-Terrest. Phy.,* **(72),** 1241–1250 **(2010)**

56. Kumar G.M., Sampath S., Jeena V.S. and Anjali R., Carbon Monoxide Pollution Levels at Environmentally Different Sites, *J. Ind. Geophys Union.,* **(12)** 31-40 **(2008)**

57. Samoli E., Touloumi G., Schwartz J., Anderson H.R., Schindler C., Forsberg B., Vigotti M.A., Vonk J., Kosˇnik M., Skorkovsky Jiri. and Katsouyanni K., Short-Term Effects of Carbon Monoxide on Mortality: An Analysis within the APHEA Project, Environ, Hea, Persp, Harvard University, **(115)** 1578-1583 **(2007)**

58. Prockop L.D. and Chichkova R.I., Carbon monoxide intoxication: An updated review, *J. Neuro. Sci.,* **(262)** 122–130 **(2007)**

59. Barbara J., Pitts Finlayson., James N. and Jr Pitts., Tropospheric Air Pollution: Ozone, Airborne Toxics, Polycyclic Aromatic Hydrocarbons, and Particles, *Sci. Mag.,* **(1997)**

60. Anenberg S.C., Jason West J., Fiore A.M., Jaffe D.A., Prather M.J., Bergmann D., Cuvel IER C., Dentener F.J., Duncan B.N., Gauss M., Peter H., Jonson J.E., Lupu A., Mackenzie A.I., Marmer E., Park J.R., Sanderson G., Michael Schultz M., Shindell T.D., Szopa S., Vivanco M.G., Wild O. and Zeng G., Intercontinental impacts of ozone pollution on human mortality, *Env. Sci. Tech.,* **(43),** 6482–6487 **(2009)**

61. WHO, Health Aspects of Air Pollution, World Health Organization **(2004)**

62. Selin N.E., Wu S., Nam K.M., Reilly J.M., Paltsev S., Prinn R.G. and Webster M.D., Global health and economic impacts of future ozone pollution, *Environ. Res. Lett,* **(4)** 1-9 **(2009)**

63. Putman E., Golde L.M.G.V. and Haagsman H.P., Toxic Oxidant Species and Their Impact on the Pulmonary Surfactant System, *J. Lung.,* **(175)** 75-103 **(1997)**

64. Gryparis A., Forsberg B., Katsouyanni K., Analitis A., Touloumi G., Schwartz J., Samoli E., Medina S., Anderson H.R., Niciu E.M., Wichmann H.E., Kriz B., Kosnik M., Skorkovsky J., Vonk J.M., Dortbudak Z., Acute effects of ozone on mortality from the Air pollution and health: A European approach Project, *Am. J. Respir. Crit. Care. Med.,* **(170),** 1080–1087 **(2004)**