International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Urbanization and Air Pollution: A Critical Review and Policy Recommendations

Dr Lakshman Chandra Pal

Assistant Professor, Department of Geography, Bidhan Chandra College, 31, G T Road(East), Rishra, Hooghly, PIN 712218, West Bengal, India

ABSTRACT

Urbanization is the process of formation of a new town or spatial expansion of the existing one. It is taking place from historic past but after industrialization gradual and large flow of rural population to the urban areas boosts up this process. Urbanization increases the density and total population in the urban areas which intensifies the interaction between the man and the environment. This in turn intensifies the rate of exploitation of natural resources. On the other hand, huge amount of green house gases like carbon-di-oxide, carbon monoxide, nitrogen oxide, sulphur-di-oxide, ground level ozone etc and particulate matters are generated in the urban areas from different anthropogenic activities like manufacturing, construction, transportation and power generation. This contaminates and polluted the air. Air pollution in the present times is one of the most serious consequences of urbanization. The contaminated air along with the polluted environment affects adversely the health of the urban people. Millions of loss of lives is the outcome. Sustainable urbanization is only the way to overcome the problems.

Keywords: Urbanization, Air Pollution, Particulate Matter, Pollutants, Carbon Dioxide

Introduction

Urbanization refers to the formation of a new town or the process of growing up of existing one so that its size become larger and larger[1]. It is a process of shifting of population from rural to urban areas with a desire for the advantages like greater opportunities to receive education, health care and services such as entertainment etc that urban areas offer[2]. Urbanization is not at all a recent phenomena rather it is taking place from historic past. So far it is known that, earliest cities were grown in Mesopotemia and Egypt. A significant increase of urban centers was noticed in the 1st millennium BCE[3]. But total number of urban population during that time was very small. In 1500 AD only 4.1% of

[1] "Urbanization in" demographic partitions. Retrieved 8 July 2015.

[2] U N World Urbanization Prospects.

[3] "Urbanization over the past 500 years". *Our World in Data*. Retrieved 6 March 2020.

* Corresponding author. Tel.: *+91-7908326500*
E-mail address: *lcpalgeo@gmail.com*

the world's population lived in urban places (U N World Urbanization Prospects). It becomes 7.3% in 1800. After industrial revolution a continuous flow of population is noticed from village to the urban centers. As a result, the share of urban population turns into 16.4% in 1900 with two million plus cities (*Patricia* A et al 2009). Thereafter it starts to grow at a faster rate. Just a half century later, it becomes 30% and urbanization gets its momentum in the developing world also. In 2007 the proportion of urban population *overrides* the rural population (rural population- 3.33 billion, urban population 3.35 billion). At present (2021) about 56.61% of the world's population live in urban areas. By 2050, the world urban population is projected to be 68%[2].

But the percentage of urban population is not equal everywhere rather a *variation* is noticed from region to region. In the developed world, more than 79.1% people at present live in urban areas whereas the same is 51.7% in the less developed regions[2]. Also the *rate* of urbanization varies from place to place. As for example, the time period taken by the London city to reach 8 million levels from 1 million population is 130 years (Madlener R. et al, 2011), but it was just 45 years for *Bangkok* (Thailand) and only 25 years for *Seoul* in South Korea (Madlener R. et al, 2011). From 1995 to 2005, the urban population in the developing world has increased by approximately 1.2 million per week (Strong A et al 2006). This unprecedented movement of people to urban centers makes the world urban population *growth curve* up till recently followed a quadratic-hyperbolic pattern.

In urban areas, number of population and its density is much higher than the country side areas. Urbanization alters the demographic pattern and intensifies the nature of economic activities which are associated with the change of land use and land cover. This plays a significant role in modifying air quality (Hopke, P.K et al 2008). Urban people interact to the environment to a greater extent, as compared to the rural populations. The city dwellers have different consumption pattern than that of rural inhabitants (Jyoti K et al, 1991). They always consume more food and durable goods than the country side populations. As for example, the Chinese urban residents consume the *pork* more than twice of rural populations (Jeffrey R et al, 1986). They also consume three times more *coal* than that of rural areas (Taylor and Hardee). It is found that, the city settler in India who are vegetarian, consume much *fruit, milk and milk products* than the rural populations (Jeffrey R et al, 1986). All of them consume much more *energy* for electricity, transportation, cooking and heating purpose. Parallel to this, huge amount of *municipal wastes* (MSW) including biomedical squander are generated in the urban areas. These are not properly processed and managed especially in low and middle income group countries. All these produce larger and larger amount of different green house gasses (GHGs) and particulate matters. This creates contamination problems in the atmosphere. Air pollution, climate change, urban heat island, global warming, etc are the outcome ie environmental crisis is the utmost consequence of urban development process. The polluted air affects adversely the health and quality of life of the urban people. Millions of loss of lives is the result. The process of urbanization also has a great impact on the social, political and economic life of the people (Kleniewski & Thomas, 2011). These in turn modify the planning and process of urbanization. Developing countries with huge population base and uncontrolled and fast industrialization are the worst victim of the problems. In general, the larger and denser is the urban population; more negative is the impacts on the environment.

This paper *reviews* the recent advances of knowledge on the impact of urbanization on air pollution and recommends some remedial measures for urban sustainability.

Methodology

The present work is carried out by studying and reviewing published literature, case studies, reports of different government and non-government organizations and official websites related to the topic. The data, literature and articles for the study were collected from the database of PubMed, ISI Web of Knowledge, Tailor and Francis, Springer, Research Gate and Google Scholar as "urbanization and the air quality" or "urbanization and Green House Gas generation" or "urbanization and the climate" or "urbanization and the Carbon-di-oxide concentration" or "urbanization and the carbon monoxide" etc. Data from NASA website have also consulted to enrich the study. From the mountainous amount of documents, these are screened firstly to a manageable number by the title, key words and the abstract. Thereafter the selected articles are thoroughly studied. Finally, the data and the information relevant to the study *"*Urbanization and Air pollution: a Critical Review and Policy Recommendations*"* are compiled for critical reflection and future recommendations for the environmental sustainability.

Urbanization and Air pollution

Air pollution in the present times is one of the most serious consequences of urbanization. As per the estimates of WHO, global air pollution has increased by 8% from 2008 to 2013 and at present 98% city dweller in the low-middle income countries and 56% in the high income countries is exposed to *unhealthy air*. The level of air pollution in the cities of the Mediterranean region and the South-East Asia exceeds 5-10 times than WHOs limit (WHO-2020). More than 7 million *adult premature deaths* per year is attributed globally to air pollution including 3.8 million from the *household sector* pollution

(Lelieveld, J et al 2019; WHO, 2014). It is about 7.7% of global total mortality (WHO 2020). The losses of economy and quality of life caused by air pollution are estimated to cost about $5 trillion per year (World Bank, 2016). Air pollution associated with urbanization increases the air temperature causing *urban heat island* and *climate change*. It changes the height of *planetary boundary layer* of air and increase daytime *ozone concentration* (Nuruzzaman Md, 2015)

Air pollution coupled with urbanization is connected with the emission of different type of *greenhouse gases* (GHGs) which are originated from diverse anthropogenic sources like industry, transportation, power generation plant, construction works and so on (Zheng M et al 2016). From these sources huge amount of oxides of carbon (Co_x), oxides of nitrogen (No_x), oxides of sulpher (So_x) and particulate matters (PMs) are discharged directly to the atmosphere causing air pollution. These are the *primary pollutants.* Apart from these there are some *secondary pollutants* like smog, chloro-fluro-carbns (CFC), peroxyacyl nitrates (PANs), nitric acid, ozone etc which are formed in the lower atmosphere by chemical reactions.

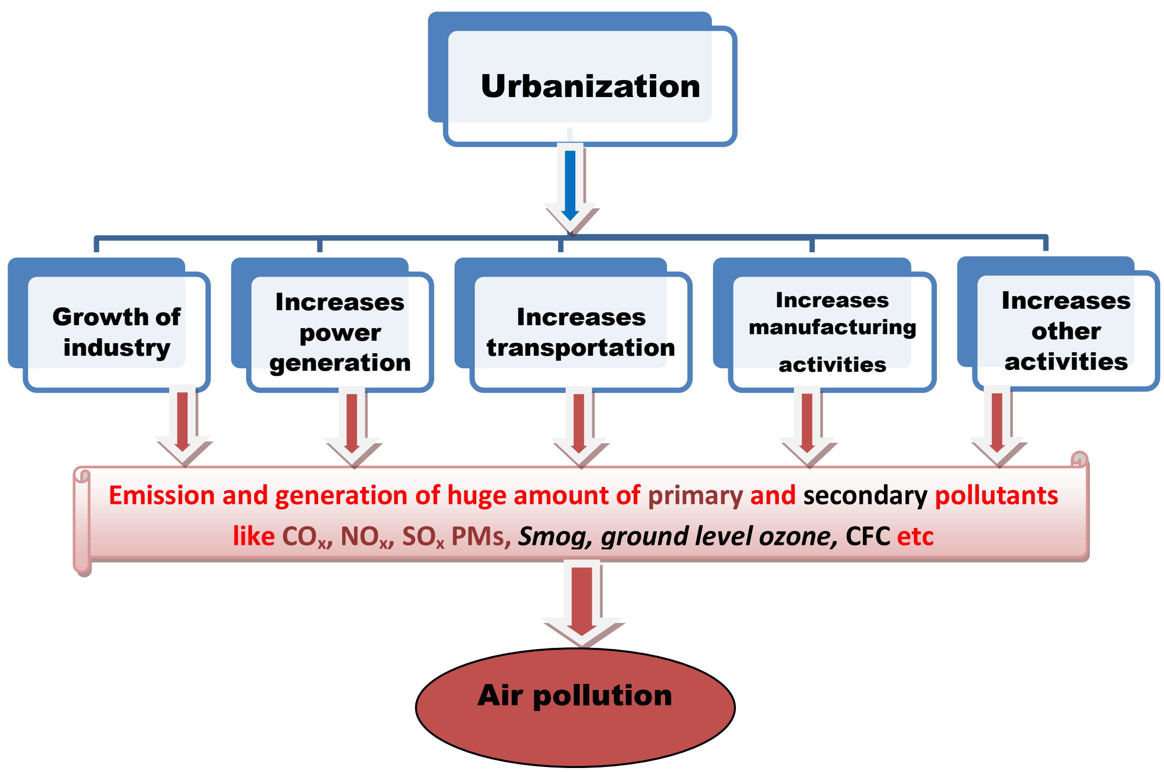

Fig-I: Urbanization and air pollution linkage.

Most important *primary air pollutants* associated with urbanization include-

Oxide of carbon (Co_x)

Oxides of carbon especially *carbon-di-oxide* (Co_2) and *Carbon-monoxide* (Co) play major role in urban air pollution. Among these, Co_2 is the most important GHG and air pollutant in the present day world. It contribute lion's share in air pollution effect in the urban area[4]. It has been noticed that, 70% of world's Co_2 is emitted out of the urban place although it covers only about 1% of the total earth's surface (Seto, K. 2014). Billions of tons of Co_2 are produced annually due to the burning of fossil fuels in the city areas. This has raised the concentration of atmospheric Co_2 by 47.5% above pre-industrial levels (Global Carbon Project. 2020). Before industrial revolution anthropogenic emission of Co_2 was not a matter of concern. But at present, its concentration has increased to 413 (ppm) parts per million (2021) from 280 ppm in pre-industrial time[5]. Upto 1950, the cities of US and Europe were the leading producer of Co_2. Thereafter, the cities of Asia, Africa, South America and Oceania kick off its generation. At present China leads all other countries in the emission of Co_2 (Global Carbon Project. 2020).

Table-I: Increase of concentration of Co_2 in the atmosphere since 1850

Year	1850	1950	1960	1970	1980	1990	2000	2010	2020	2021
Co_2 concentration (ppm)	280	315	319	328	339	355	370	390	413	415

Source- CO2.earth/ Mouna Loa Observatory, Hawaii, NOAA-ESRL

Carbon Monoxide is produced as a result of the incomplete combustion of carbon of fossil fuels and so the transport sector is the main source of Co generation. Air-to-fuel ratio in motor vehicles has a direct impact on carbon monoxide emissions. It has been found that, lower is the ratio, higher is the emission of carbon monoxide due to incomplete combustion in low presence of oxygen. In urban areas, the emission of Co in the urban air reaches to a maximum in the early morning and in the late afternoon hours due to peak traffic intensity and decrease to low levels at night. The amount of anthropogenic sources of carbon monoxide in the atmosphere has been constantly increasing during the last few years in most of the urban areas. The *Measurements of Pollution in the Troposphere* (MOPITT) sensor on NASA's Terra satellite observations shows a significantly higher concentration (more than 300 parts per billion, ppb) of Co in eastern China, USA and Europe[6].

[4] "Air Pollution Causes, Effects, and Solutions". National Geographic. 9 October 2016.

[5] "Graphic: The relentless rise of carbon dioxide". Climate Change: Vital Signs of the Planet. NASA.

[6] Homepage for NASA Earth Observations/ Feb 1, 2007 to Feb 28, 2007 carbon monoxide satellite image from NASA Earth Observations (NEO). Details.

Oxides of nitrogen (No_x)

Oxides of nitrogen include mainly nitrogen dioxide (No_2) and nitric oxide (NO). Nitrogen dioxide plays a big role in urban air pollution. It aids in the formation of another deadly gas; ozone. It is also known as *killer gas*. No_2 is mainly a traffic related pollutant, emitted out of the automobile sector and so its concentration is peaked with crest of the traffic (Richmont-Bryant J et al 2017, Hesterberg TW et al, 2009). Industrial emission is also a prime source of this gas. Huge amount of No2 is generated also from heating and power generation systems. No_2 level in the atmosphere has risen dramatically since 1990 which is a matter of worrying.

Oxides of sulpher (So_x)

Sulphur dioxide; a critical pollutant, is sourced in the urban atmosphere from the combustion of fossil fuels by oil refineries, automobiles, thermal power plants, acid plants, smelters, incinerators and so on. It has been estimated that about one third of the sulphur dioxide emission in the atmosphere arises from the activities of man chiefly from the combustion of fossil fuels.

Particulate matter

Particulate matters (PMs) including $PM_{2.5}$ (diameter of less than or equals to 2.5 micrometer) and PM_{10} (diameter of less than or equals to 10 micrometer) are the key source of present day air pollution in the urban areas claiming 4 million death per annum globally (WHO, 2019). These are burdened with toxic heavy metals like sulphate, nitrate, organic carbon, elemental carbon, soil dust, sea salt etc and are small enough to enter easily deep into the lungs (Chen and Lippmann, 2009). Study shows that, due to high concentration of particulate matters in the air, lung cancer have increased by 465% since 1980 in the urban areas (Liu, L., 2010). The PMs are generated mainly from the combustion of vehicles, burning of residential or industrial fuel, industry, mining, the application of agricultural pesticides and fertilisers, trains, shipping, road and air travel and from some secondary sources (Guo, et al 2019), although there are some natural sources of PMs like volcanic eruption, forest fire etc. The production and concentration of PMs are highly correlated with the consumption of energy (Klimont et al. 2017) and type of activities performed. Human exposure to particulate matters is higher in the urban areas where people, traffic, industries and so the pollutants are largely concentrated. In the cities of Mediterranean and East and South East Asian countries, the concentration of PMs especially $PM_{2.5}$ is significantly larger than WHOs admissible level (WHOs annual mean level of $PM_{2.5}$ =10 μg/m^3, PM_{10} =20 μg/m^3)[7]. This area is known as the *$PM_{2.5}$ hotspot zone*. In different Chinese cities, the concentration of $PM_{2.5}$ level in some nights turns into 22% more than the normal level of the country (Liu J et al 2016). About 83% people here are exposed to $PM_{2.5}$ level which is beyond the Chinese ambient air quality standard of 35 μg m^{-3} (Liu J et al 2016). The world's highest concentration (annual mean) of $PM_{2.5}$ (99.73 μg m^{-3}) is observed at present in Nepal, whereas it is the lowest in the cities of Sweden, Finland, Iceland, Canada and New Zeland (6 μg m^{-3})[8]. The worst polluted city in the world in terms of $PM_{2.5}$ concentration and PM_{10} concentration are Kanpur ($PM_{2.5}$ = 195 μg m^{-3}) and Delhi (PM_{10} = 367 μg m^{-3}), India respectively[9]. Among the most (air) polluted 15 cities in the world in terms of $PM_{2.5}$ concentrations, India includes 14[10].

Table-II: Concentration of particulate matters in the atmosphere in different countries.

Sl no	Name of the countries	$PM_{2.5}$ (μg/m^3) concentration	Name of the countries	PM_{10} (μg/m^3) concentration
1	Nepal	99.73	India	349
2	Niger	94.05	Thailand	315
3	Quarter	91.19	China	236
4	India	90.87	Afghanistan	203
5	S. Arabia	87.95	Uganda	181
6	Egypt	87.00	Pakistan	174
7	Cameroon	72.79	Nepal	171
8	Nigeria	71.80	Laos	166
9	Bahrain	70.82	Myanmar	166
10	Chad	66.03	Uzbekistan	164

The GAIA air quality monitoring stations, Ranking updated 11 hours ago (Feb 28, 2021).

[7] WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide - Page 11

[8] Brauer M et al, 2017 for the Global Burden of Disease Study

[9] CPBC-Central Pollution control board, (2020), http://cpbc.nic.in/

[10] WHO's Global air pollution database released in Geneva

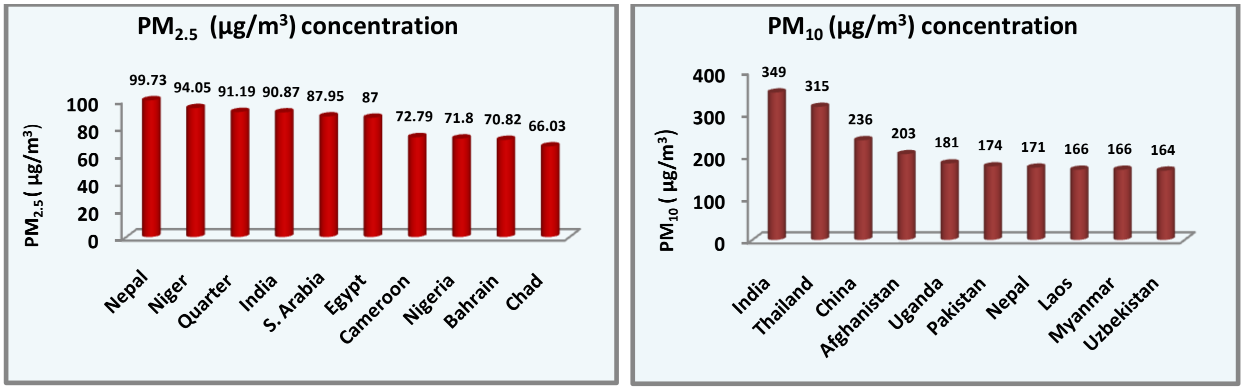

Fig-II: Distribution of concentration of PMs in the atmosphere over the cities in different countries. (Source-Table-2)

Secondary pollutants also have a great impact on air pollution in the urban environment. These are not directly attributed to the nature and are produced as a result of the reactions in the atmosphere. These include chlorofluorocarbons (CFC), smog, acid rain, ground level ozone, peroxyacyl nitrates (PANs), nitric acid etc. Haze pollution is very common in different Chinese and Indian cities claiming huge number of deaths (Huang RJ et al 2014). In 1948, thousands of city dwellers are *died* or *sickened* in Donora, Peru and 3000 people died in London in 1952 for *London fog*, created due to the presence of high levels of sulfurous smog in the air (Bell and Davis, 2001). Photochemical air pollution is resulted from the reactions involving nitrogen oxide (No_x) and volatile organic compounds (e.g., ethylene and benzene) that produce ozone (O_3). *Ground level ozone* is formed through dissociation of nitrogen oxides (No_2) in the sun by photochemical reaction. It is higher in such cities having higher vehicle density like USA or Western Europe[11].

It has been observed that, the *level of air pollution* in the cities is directly related to the level of urbanization in terms of its population and functions (Wang S et al 2014). In a study, Parrish & Zhu concluded that, the concentration of primary pollutants in urban places develops as a function of power law of population; Nβ, where N is total population and β is the exponent (Value of β is in between 0 and 1) (Parrish DD et al 2009). It has been observed that, increasing 1% of urbanization leads to 1.37% increase of contamination dispersal (Wang S. et al, 2014). But the rate of emission and type of pollutants varies from city to city and place to place depending on the population size, stages of development and function of the cities, location and climate type of the cities. The cities of Mediterranean and south East Asian countries including China and India are suffering today from notoriously bad air quality (Han L,

[11] WHO, Air Quality Guidelines

et al 2016) whereas in North America, Europe, and Latin America the city dweller enjoy better air (Han L et al 2016). In latter case, *transport emission* is the sole reason of urban air pollution but air in the former areas is polluted by *diversified sources* (Baklanov A et al 2016).

There is a major *variation* in urbanization along with air pollution across the world. Some countries are able to develop a satisfying urbanization with low levels of air pollution during 1990–2012 (e.g., Denmark (urbanization: 83.09%; air pollution intensity: 1.01 kt of CO2 equivalent/hundred billion dollars); some others achieve high-level urbanization, but there air pollution is also serious (e.g., Russia (urbanization: 68.93%; air pollution intensity: 5.912 kt of Co_2 equivalent/hundred billion dollars)); others' urbanization maintain a low-level, but air pollution has been severe (e.g., Vietnam (urbanization: 21.71%; air pollution intensity: 5.66 kt of Co_2 equivalent/hundred billion dollars) (Qing WANG, 2018).

Conclusion and Potential strategies of environmental sustainability

It is predicted that, by 2050, about 64% people of the developing world and 86% of the developed world will reside in the urban places[12] creating more and more pollution to the atmosphere especially in the developing countries. In such a situation the *governments*, *planners, policy makers, think tanks* and the *political bodies* must have to think about *sustainable urbanization strategy* by following multidisciplinary approach in formulation and implementation of urban development plans. Because, solving the pollution problems of the city would be a major contribution to solve the global atmospheric pollution for it is in cities where the greatest concentration of population and economic activities are noticed. They must keep in mind, the impacts of urbanization on poverty, inequality, employment, services, transport, climate change and politics. The situation of population trends over long run and the dimensions of sustainable development: *economic, social and environmental* must be kept in mind during policy making and formulation. This will maximize the benefit of agglomeration and minimize the impact of environmental degradation and other potential adverse impacts, making *urbanization sustainable*. Here is an outline of the potential strategies; the world can take to achieve global environmental sustainability.

1. **Sustainable industrialization**- Industrial development is utmost necessary for the economic growth and development of any country. This is highly an energy intensive sector and so the main offender for environment pollution. For *industrial sustainability*, it is essential to use

[12] "Urban life: Open-air computes". The Economist, 27 October 2012, Retrieved on 20 March 2013

cleaner energy and technologies and strong energy efficient policies (Pan, 2016). Also there may be a separate *industrial huddle* away from the settlement area. This in one hand will decrease the amount of pollutants to the domestic neighborhood and on the other hand will develop the industrial clusters by supplying the waste or by product of one industry to be used by the others (Hysa et al., 2020)

2. **Green Urbanism**- The principle of green urbanism must be followed in urban planning. For this deep green passive design strategies and solar architecture concept for all buildings be implemented. This will make the buildings cool in summer and warm in winter by catching the sun. It may bring down the demand of electricity for cooling and heating purpose. Also, the principle should be based on the *triple zero framework* of zero fossil fuel energy use, zero waste and zero emission aspiring for low-to-no carbon emissions.

Fig-III: Potential strategies for global environmental sustainability

3. **More use of green and public transport-** Transportation sector is one of the largest producers of GHGs, PMs and other different type of wastes. So to minimize these, people should use the public transport system more than their private cars. All the vehicles be shifted to BS-VI emission standards to reduce the emission. Use of bicycle also be encouraged. This will decrease the emission potential and will be beneficial for the health also. *Public bike sharing* system (PBS like China) also be encouraged. Along with this, traffic management system should be improved. Agricultural burning must be stopped.
4. **More use of renewable energy-** *Renewable* sources of energy like hydropower, solar, wind, geothermal, biomass etc are environment friendly. More use of low-emissions fuels and renewable combustion-free power sources decrease the use of fossil fuels and so the emission of GHGs. (Ellabban et al., 2014). For this the poor people living below poverty line may be provided with free LPG connection (like UJJALA project in India) to reduce household pollution. The access to *clean energy* is considered as an indicator for sustainable energy (SDG-7). It should be affordable and the government should take initiative to make the availability of the technologies and instrument of renewable energy sources to the public.
5. **Recycling and reuse of wastes-** Haphazard dumping and management of different types of wastes greatly deteriorates the quality of the air, the soil and the water. Majority of the people especially in developing countries have no proper idea about the segregation and disposal of wastes (Rahman et al, 2020). So, proper management system must be adopted in this sector especially in case of the management of infectious and hazardous medical waste before it enters into the environment. Private-public-Partnership (P-P-P) model may be adopted in this case. Emphasis must be given in reuse and recycle in wastes.
6. **Proper treatment of MSW and waste water**- MSW and waste water from industrial sites and municipalities is a major source of land and water pollution throughout the world. So, suitable strategies for waste reduction, waste separation, recycling and reuse or waste should be adopted. Waste water must be treated properly before discharging. Also reuse of this type of water after proper treatment may be encouraged in some *non-drinking* and *non-production* processes.
7. **International cooperation**- Pollution especially air pollution does not recognize boarders. So, courtiers must work together on solutions for sustainable transport, more efficient and renewable energy production and the management of waste. For this, the international bodies like United Nations (UN), World Health Organization (WHO), International Energy Agency (IEA),

Grantham Institute-Climate Change and Environment, European Commission (EC) etc should take initiatives to prepare time-oriented policies and their proper implementations throughout the globe especially in developing countries (Meredith, S, 2020).

Acknowledgement- Not applicable.

Abbreviation

MSW- Municipal Solid waste

NASA- National Aeronautics and Space Agency

WHO- World Health Organization

GHG- Green House gase

CO_2- Carbon-di-oxide

NO_2- Nitrous oxide

CO- Carbon monoxide

PMs- Particulate matters

So_2- Sulphur di-oxide

N_2O- Nitrous oxide

CH4- Mithen

MOPITT- Measurements of Pollution in the Troposphere

$PM_{2.5}$- Particulate matter having diameter of less than or equals to 2.5 micrometer

PM_{10}- Particulate matters having diameter of less than or equals to 10 micrometer

$\mu g\ m^{-3}$ – Microgram per cube meter

CFC- chlorofluorocarbons

pCB- Polychlorinated biphenyls

COVID-19- Corona virus 2019

IPCC- Intergovernmental Panel on Climate Change

SDG7- Sustainable Developmental Goal 7

P-P-P – Private-Public-Partnership

UN- United Nations

IEA- International Energy Agency

EC- European Commission

References

1. Baklanov A, Molina LT, Gauss M. 2016. "Megacities, air quality and climate". Atmos., 126:235– 49
2. Bell, M. L., and D. L. Davis (2001), Reassessment of the lethal London fog of 1952: Novel indicators of acute and chronic consequences of acute exposure to air pollution, *Environ. Health Perspect.*, 109(3), 389–394.
3. Chen, L. C., and Lippmann, M. (2009). Effects of metals within ambient air particulate matter (PM) on human health. *Inhal. Toxicol.* 21, 1–31. doi: 10.1080/08958370802105405 PubMed Abstract | CrossRef Full Text | Google Scholar
4. Ellabban O., Abu-Rub H., Blaabjerg F. Renewable energy resources: current status, future prospects and their enabling technology. Renew. Sustain. Energy Rev. 2014;39:748–764. [Google Scholar]
5. Global Carbon Project. (2020). Supplemental data of Global Carbon Budget 2020 (Version 1.0) [Data set]. Global Carbon Project. https://doi.org/10.18160/gcp-2020
6. Guo, H., Kota, S. H., Sahu, S. K., & Zhang, H. (2019). Contributions of local and regional sources to PM2.5 and its health effects in north India. Atmospheric Environment, 214, Article 116867.
7. Han L, Zhou W, Pickett STA, Li W, Li L. 2016. An optimum city size? The scaling relationship for urban population and fine particulate (PM2.5) concentration. Environ. Pollut. 208:96–101
8. Hesterberg TW, Bunn WB, McClellan RO, Hamade AK, Long CM, Valberg PA. Critical Review of the human data on short-term nitrogen dioxide (NO_2) exposures: evidence for NO2 no-effect levels. *Crit Rev Toxicol*. (2009) 39:743–81. doi: 10.3109/ 10408440903294945 PubMed Abstract | CrossRef Full Text | Google Scholar
9. Hopke, P.K.; Cohen, D.D.; Begum, B.A.; Biswas, S.K.; Ni, B.; Pandit, G.G.; Santoso, M.; Chung, Y.-S.; Davy, P.; Markwitz, A. Urban air quality in the Asian region. Sci. Total Environ. 2008, 404, 103–112

10. Huang RJ, Zhang Y, Bozzetti C, Ho KF, Cao JJ, et al. 2014. "High secondary aerosol contribution to particulate pollution during haze events in China". Nature 514:218–22
11. Hysa E., Kruja A., Rehman N.U., Laurenti R. Circular economy innovation and environmental sustainability impact on economic growth: an integrated model for sustainable development. Sustainability. 2020;12:4831. [Google Scholar]
12. Jeffrey R. Taylor and Karen A. Hardee, Consumer Demand in China: A Statistical Factbook (Boulder, CO: Westview Press, 1986): 112.
13. Jyoti K. Parikh et al., Indira Gandhi Institute of Development Research, "Consumption Patterns: The Driving Force of Environmental Stress" (presented at the United Nations Conference on Environment and Development, August 1991).
14. Kleniewski, N., & Thomas, A. R. (2011). *Cities, change, and conflict* (4th ed.). Belmont, CA: Wadsworth.
15. Klimont, Z., K. Kupiainen, C. Heyes, P. Purohit, J. Cofala, P. Rafaj, J. Borken-Kleefeld, and W. Schöpp. 2017. Supplement of global anthropogenic emissions of particulate matter including black carbon. *Atmos. Chem. Phys.* 17 (14):8681–723. doi:10.5194/acp-17-8681-2017. [Crossref], [Web of Science ®], [Google Scholar]
16. Lelieveld, J.; Klingmüller, K.; Pozzer, A.; Burnett, R. T.; Haines, A.; Ramanathan, V. (25 March 2019). "Effects of fossil fuel and total anthropogenic emission removal on public health and climate". Proceedings of the National Academy of Sciences of the United States of America. **116** (15): 7192–7197. Bibcode:2019PNAS..116.7192L. doi:10.1073/pnas.1819989116. PMC 6462052. PMID 30910976. S2CID 85515425.
17. Liu, L. (2010). Made in China: cancer villages. *Environ. Sci. Policy Sustain. Dev.* 52, 8–21. doi: 10.1080/00139151003618118 CrossRef Full Text | Google Scholar PubMed Abstract | CrossRef Full Text | Google Scholar
18. Liu J, Mauzerall DL, Chen Q, Zhang Q, Song Y, et al. 2016. "Air pollutant emissions from Chinese households: a major and underappreciated ambient pollution source". PNAS 113:7756–61
19. Madlener R. Sunak Y. "Impacts of Urbanization on Urban Structures and Energy Demand: What Can we Learn from Urban Energy Planning and Urbanization Management?" Sustainable Cities and Society, 1, pp. 45-53., 2011

20. Meredith, S. (18 June 2020). "IEA outlines $3 trillion green recovery plan for world leaders to help fix the global economy". CNBC. Retrieved 25 June 2020.
21. Nuruzzaman. Md., "Urban Heat Island: Causes, Effects and Mitigation Measures - A Review" (2015) International Journal of Environmental Monitoring and Analysis; 2015, 3(2): 67-73, ISSN: 2328-7659 (Print); ISSN: 2328-7667 (Online), (http://www.sciencepublishinggroup.com/j/ijema) doi: 10.11648/j.ijema.20150302.15
22. Pan J. China's Environmental Governing and Ecological Civilization. China Insights. Springer; Berlin, Heidelberg: 2016. Sustainable industrialization. [Google Scholar]
23. Parrish DD, Zhu T. 2009. Clean air for megacities. Science 326:674–75.
24. Patricia C. A., and Robert M. B. (2009), "Urbanization and growth: Setting the context", Washington, DC : Commission on Growth and Development : World Bank, c2009 , *ISBN 978-0-*8213-7573-0, Bib Id 4585148
25. Qing WANG, (2018), "Urbanization and Global Health: The Role of Air Pollution", Iranian Journal of Public Health, 2018 Nov; 47(11): 1644–1652. PMCID: PMC6294869, PMID: 30581779
26. Rahman M. Rare dolphin sighting as Cox's Bazar lockdown under COVID-19 coronavirus. 2020. https://www.youtube.com/watch?v=gjw8ZllIlbQ
27. Richmont-Bryant J, Owen RC, Graham S, Snyder M, McDow S, Oakes M, et al. Estimation of on-road NO2 concentrations, NO2/NOX ratios, and related roadway gradients from near-road monitoring data. Air Qual Atm Health. (2017) 10:611–25. doi: 10.1007/s11869-016-0455-7. CrossRef Full Text | Google Scholar
28. Seto, K. 2014, "Climate Change: Mitigation of Climate Change". IPCC Working Group III Contribution to AR5 (Cambridge University Press, New York, 2014).
29. Taylor and Hardee, *Consumer Demand in China*: 125.
30. U N World Urbanization Prospect: The 2018 Revision, Economic and Social Affairs (Key Facts) and Historical source
31. Wang S, Fang C, Guan X, Pang B, Ma H. 2014. "Urbanization, energy consumption, and carbon dioxide emissions in China: a panel data analysis of China's provinces". Appl. Energy 136:738–49

32. World Health Organisation (2014). *7 Million Premature Deaths Annually Linked to Air Pollution.* Available at: http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/ [accessed January 29, 2018]. Google Scholar
33. WHO (2019)- Global Air Pollution Database (update 2016), Available at: https:// www.who.int/airpollution/data/cities/en/ (accessed August 1, 2019).
34. WHO (2020)- World Health Organization Air pollution. Available online at: https: //www.who.int/ health-topics/airpollution. Accessed 15 May 2020. Google Scholar
35. World Bank; Institute for Health Metrics and Evaluation at University of Washington – Seattle (2016). The Cost of Air Pollution: Strengthening the Economic Case for Action(PDF). Washington, D.C.: The World Bank.
36. Zheng M, Yan C, Li X. (2016). PM2.5 "Source apportionment in China. In Issues in Environmental Science and Technology", ed. X Querol, RM Harrison, RM Harrison, RE Hester, pp. 293–314. London: Royal Soc. Chem.