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ARTICLE

CLIMATE CHANGE AND URBAN AREAS OF INDIA

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While most public discussions on climate change focus on carbon emissions, there are several other causative agents, many of which originate from our growing urban regions. In this article, we first explore what climate change means for urban areas, particularly how extreme weather events affect them. We then look at some of the causative factors: modern sewerage systems, solid waste dumps, refrigerant gases, organic solvents, dust, etc. With examples from cities in India, we discuss how these agents contribute to climate change. To conclude, we reflect that the journey to find alternatives for these causative agents is a difficult one. However, if we understand the inter-relationships between different aspects, we could then re-conceptualize urban spaces as well as our lifestyles, and this effort may bring pleasant surprises.

Introduction

The discourse of climate change in most public fora (media, politics, science textbooks) is often centered around carbon emissions, carbon credits and use of fossil fuels versus renewable energy sources. This discourse sometimes gives the impression that carbon dioxide emissions are the sole determinant for global warming (due to greenhouse effect) and hence their increase is the exclusive cause of climate change. This overly simplified picture under-estimates several other greenhouse gases which increasingly and significantly contribute to changes in climate. These components include nitrous oxide, methane, halocarbons and other halogenated gases, some other carbon compounds and a variety of aerosols or particulates, each originating from different sources such as power plants, vehicles, agriculture, ruminant animals, solid and liquid wastes, forests, grasslands, industries, water bodies, household devices etc. Carbon dioxide is undoubtedly the major causative factor for climate change, currently accounting for around 76 percent of greenhouse gases, with around three-fourths of it lasting up to 200 years in the atmosphere and the rest continuing to exert influence for over 1000 years. However, the impact of these other gases, albeit existing in smaller quantities in the atmosphere, can be even greater than that of carbon emissions, although for shorter durations. For example, one of these gases, methane has around 34 times more "global warming potential," as it is termed, than carbon dioxide over a period of 100 years, nitrous oxide over 300 times more, and some halocarbons are over 20,000 times more powerful warming agents than carbon dioxide.[1] On the other hand, these gases have a shorter life in the atmosphere than carbon dioxide, degrading into other less harmful compounds far quicker than the chemically more stable carbon dioxide, and are hence termed "short lived climate forcers" (SLCF). Some experts therefore argue that actions to reduce SLCFs would yield more immediate dividends than reduction of carbon dioxide, and hence should be pursued more vigorously.[2]

In this article, we shall focus on urban areas and reflect upon how urban scenarios are affected by and respond to climate change and how these, in turn, contribute to the problem. While urban areas make up a small (but increasing) fraction of the earth's surface, they are host to over half the global population and, due to the characteristics of urban living, have quite significant impacts on the local ecology and the climate. Urban inhabitants in India, while having significant potential to influence policy makers, are not very aware of the causative

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agents of climate change in their surroundings. All these factors add to the importance of a discussion on the urban scenario in the context of climate change.

Like in many other countries, there is a strong trend of urbanization in India, in terms of both rising urban population including through rural-urban migration, and a growing urbanization of rural areas. Urban spaces are characterized by the use of more organized facilities such as piped water supply, sewerage systems, electricity supply, more compact and densely populated residential areas, considerable commercial, industrial and office buildings and activities, motorized transports, as well as higher household use of powered appliances, consumer products and services. Rapid technological changes also tend to find ready, substantial response from urban consumers leading to considerable economic and environmental impact. However, the consuming populace often takes long to realize the significance of this impact, for example rising ownership of passenger vehicles leading to high levels of air pollution. In the climate change discourse relating to urban areas, a significant discussion already exists about high energy consumption in urban areas such as through higher use of personal vehicles and high consumption of electricity, especially air conditioners. Here we will talk about some less discussed aspects of urban life which interplay with climate change.

How Cities Respond to Climate Change

While most of us may not feel the change in global average temperature, we do experience and acknowledge impacts of climate change such as extreme weather events like extended heat or cold spells, drought, or extreme rainfall and flooding. A certain class of urban dwellers may sometimes not perceive changes in the climate either because their lives are not directly impacted by it in the way a farmer's life is intimately bound to the seasons and rainfall patterns, or may simply remain oblivious to them because they spend much of the day in air-conditioned environments. So let us look at different manifestations of climate change in urban environments, some of which are quite different from those in rural or even semi-urban spaces.

High Temperatures : There is no dearth of evidence that average temperatures have risen all over the world by around 0.8°C since the late 19th century[3], with some countries such as India with near-equatorial and tropical regions registering even higher temperature rise[4]. Many parts of the world, including in Europe which are not accustomed to such phenomena, have also experienced unprecedented heat waves in recent times, and with increased frequency.[5] In cities, temperatures generally tend to be even higher, often by as much as by 1°C, due to concretization, radiation off such surfaces, trapping of heat and what are known as "Urban Heat Islands" (UHI).[6]

Such high surface temperatures and heat spells lead to increased use of cooling devices especially air-conditioners, not just in developed countries, but also in India and other developing countries due to the rise of a newly-affluent and sizeable middle class. Increased use of air-conditioners results in release of additional heat into the ambient air, further contributing to temperature increase in the surroundings. Air-conditioners and refrigerators also use dangerous greenhouse gases, which eventually get released into the atmosphere as discussed in more detail later.

The abnormal increase in heat also significantly affects the microbial ecology of the environment. The heat either decreases the density and activity of decomposing microbes in the environment or increases it abnormally.[7] Change in density of decomposing bacteria affects several processes around us such as more rapid spoiling of food, and curd not setting properly. Solid waste may not decompose in time, causing higher accumulation, or start fermenting too fast, creating oxygen deficiency in the local air. Temperature rise can sometimes also retard growth of some pathogens such as malarial parasites, and promote growth of others.[8]

Increased temperatures also lead to increase in water demand, which severely affects the lives of lower income groups while better-off sections of the population receive higher shares of available resources or can supplement shortages with their own funds. Rates of evaporation also increase, further shrinking water availability and often increasing pollutants' concentrations in surface water bodies.

Urban spaces also contain high amounts of evaporated solvents and volatile chemicals from various cleaners, aerosol propellants, and fuel pumps, which further increase during periods of high temperature and heat spells. Increased amounts of volatiles and solvents also lead to changes in ozone concentrations in local air resulting in high ozone days (when 8-hr average concentration of ozone is higher than 70 parts per billion),[9] which adversely affects human health and local ecology, as well as further contributes to greenhouse gases. The indirect effect of ozone in reducing the ability of ecosystems to sequester carbon dioxide is much more significant than its impact as a greenhouse gas.[10]

Cold spells : Even though the prominent manifestation of increased greenhouse gases is in the form of increased surface temperatures, higher frequency and longer duration of heat waves, there have been occasions of unusual cold spells in Europe[11] and the US[12], although less than heat waves. While in many parts of India too, the intensity and duration of cold days during winters are decreasing, north central India (including parts of the western Himalayas and much of the Indo-Gangetic plain) and parts of north east India are experiencing longer cold spells.[13] In many of these cases, more cold days are often accompanied by smog or fog. Even when temperatures in these regions do not drop below 0°C, the changes in durations of cold periods, accompanied by changed wind patterns affects air quality with negative impact on human health as well as socio-economic activities in urban areas.[14]

Unusual cold spells, most importantly, increase the already high consumption of energy for heating homes, offices, etc. Bacterial and microbial activity decreases, and therefore performance of composting and sewage treatment plants decreases, leading to increased accumulation of un-decomposed waste in the plants. The cold spells also affect the long term health and evolution of plants, birds and insects,[15] which affect gardens and the (limited) green spaces existing in cities. While these effects are more pronounced in temperate zones due to sub-zero temperatures, some of these impacts are also becoming visible in Indian cities.

Drought : While many parts of Western India are observing fewer droughts than before, eastern, central and north-eastern regions of India are facing increasing drought events, both in duration and magnitude.[16] Even areas which faced heavy floods are facing drought like situation within months.[17] Part of the problem is due to changed temporal pattern of rain and partly to changing hydrogeology due to human activity. Another prominent example of such situations is several Himalayan towns where perennial springs are becoming seasonal despite floods during heavy rainfall, which is often reducing in temporal spread.[18] In addition to affecting basic necessities such as drinking, cooking and washing, drought also risks the failure of modern toilets and connected sewerage systems in cities, that are built on an assured water supply. Dry spells also reduce moisture levels in soil, vegetation and air. Under such situations, increased incidents of wildfire have been observed in parts of India, e.g. western ghats in Maharashtra state.[19] While many of these fires originate in forests or sub-urban areas, they affect nearby urban settlements also. Under any condition, these fires produce a lot of heat and lead to heating of the local air.

Lack of water recycling and reuse practices lead to loss of available water in the form of wastewater after single use. Hence large scale efforts are needed to ensure replenishment of groundwater and surface sources, as well as to put in place systems for recycling and reuse of the (large) amounts of water consumed by an increasingly urbanized populace. A recent drought in the state of California, USA, which ran from 2012 to 2016, impacted the household water supply, outdoor recreation, local ecology, and commercial projects.[20] However, total economic losses to the state over 5 years were only about 0.09%. This was because, by learning from past severe droughts, the state had prepared itself by implementing water conservation, storage, wastewater reuse practices, some voluntary and sometimes mandatory.

Excessive rains and floods : In the recent past, and as predicted by climate scientists, many regions in India are experiencing heavy rainfall events, with rainfall in excess of 300 mm in a single day, leading to floods even in desert areas of Rajasthan[21] and Gujarat, and well-drained coastal areas of Kerala. Cities and urban areas, in particular, have been seriously affected. Urban flooding, for example in Chennai and Mumbai are believed to have been exacerbated by changed hydro-geologies due to haphazard manipulation of river and other drainage systems, construction activities on river flood plains and over natural drainage lines, excessive concretization preventing seepage of rainwater into ground, as well as under-designed and poorly maintained urban drainage systems such that they are unable to handle even normal heavy monsoon rains, leave alone extreme rainfall events. Poor urban infrastructure, unplanned urban development, ineffective and unaccountable governance, all further worsen the situation.

The water supply infrastructure, often located next to water bodies, are one of the first to be impacted by sudden floods, particularly the pump motors and electrical switchgear.[22] One of the common risks of floods in urban areas is mixing of sewage with flood water, which increases risks of disease outbreaks.[23] In cities lacking sewage treatment systems, where sewage is treated through stabilization ponds or flows raw through open drains into water bodies, this risks becomes even worse, although regions with sewage treatment facilities also succumb to heavy flooding. This is typically dealt with by resorting to excessive chlorination of drinking water and sometimes of the flood waters, which also has long term ecological impacts. In many places, floods also wash away accumulated solid waste, and dilute pollutants in water bodies, while depositing new silt or sludge at other places.[24]

How Cities Contribute to Climate Change

We have so far seen how urban systems are affected by extreme weather events, which often are manifestations of global climate change. Here it is important to realize that cities are not just on the receiving end of this problem, but also contribute to the problem in significant ways. As per a recent report, cities, while occupying only 2% of the global land area, consume 78% of global energy and account for 60% of global greenhouse gas emissions[25]. Here we look at some of the major causative agents of climate change originating especially in urban areas.

Concretized infrastructure : The process of urbanization with huge built-up area and elaborate service infrastructure leads to massive land use change and loss of biodiversity. A lot of natural open space is replaced by concretized infrastructure such as roads, buildings, pavements, recreation spaces, waterfronts etc., which prevent growth of carbon-absorbing vegetation, reduce groundwater recharge (disturbing the hydrological cycle), and add to local heat.[26]

High use of energy : City life is marked by a lifestyle which uses more energy, mechanized systems and rapid movement of human beings. This is facilitated by intensive transportation which uses significant amounts of fossil fuels leading to high emissions. Even electricity-based systems involve large amount of heat release, which lead to heating up of local atmosphere. Heating and cooling systems meant to regulate temperature in homes, offices and shopping malls result in net release of heat to the environment, apart from the direct release of GHGs. Studies indicate that air conditioning use at night-time can itself lead to an increase of 0.25-1°C rise in night time air temperatures locally.[27]

Current Sewage Systems : Modern sanitation systems are based on using large amount of water to carry all manner of household waste water including toilet-flush water, as well as some industrial waste water that may or may not have been treated at source, and habitat run-off in storm-water drains, away from living areas. The sewage is expected to be treated in waste treatment plants to bring the water to acceptable standards laid down by the World Health Organization internationally, and by the Bureau of Indian Standards in India, to render it fit for discharge into drains, water bodies or land. More modern plants especially in developed countries increasingly separate waste streams into “black water” or streams carrying faecal matter, and “grey water” or water without faecal matter such as bath, kitchen or household cleaning waste, and treat these separately for different uses, with the latter being recycled including for flushing toilets etc. Sewage Treatment plants (STPs) are designed to reduce Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Suspended Solids, and better STPs would also remove other impurities or contaminants in the waste waters.[28]

Waste waters are treated in two main steps. The first is decomposition of faecal and other organic matter by microbes and for generation of gas. A portion of the decomposing matter remains in the sewage in the form of suspended matter which settles down as sludge leaving relatively clean water, which is then further treated with aerobic and anaerobic methods before discharge. Major fractions of non-metallic elements such as carbon, hydrogen, nitrogen and sulphur are converted into gases like carbon dioxide, hydrogen sulphide, nitrous oxide, ammonia etc, most of which are potent greenhouse gases. Consequently, the sludge has higher concentration of metals than is usually obtained from decomposed biomass, due to which it is often considered toxic for use even in agricultural fields. In most Indian STPs, there is little or no capture of these gases which are either directly vented into the atmosphere, sometimes spontaneously catching fire, or are deliberately set on fire atop flare towers resulting in generation of carbon dioxide and considerable heat. Recently, this aspect has been identified and captured in policy documents toward plans for Climate Change mitigation.[29]

Sewage systems in India also suffer from fundamental technical and social design problems, reflected by the large number of sanitation workers involved in unhygienic, socially discriminatory and dangerous manual operations, with many deaths being reported while workers clean or repair sewage lines, septic tanks or sewage treatment plants.[30] Most of these deaths are due to asphyxiation and inhalation of toxic gases such as methane, hydrogen sulphide, and phosphine produced largely from highly anaerobic conditions prevalent at these sites. Municipal authorities have somehow not felt the necessity of scientific design and technical management of these systems, also evidenced by the fact that most of the sanitation workers are rarely properly trained. Current sewage systems in India with strongly anaerobic conditions are a major contributor of greenhouse gases and hence to climate change.

Solid Waste : Cities and urban areas are also notorious for producing large amounts of solid waste, both organic mostly food wastes and a variety of non-biodegradable recyclable and non-recyclable wastes. Landfills in India are not technically designed or managed, and are really large mounds of miscellaneous mostly non-segregated waste. This creates anaerobic conditions inside the piles which cause generation of methane which often catches fire spontaneously. Fires in landfills have often been quite severe and long-lasting, and have been noted in the media both nationally and internationally. The 2016 fires in the Deonar dumping ground in Mumbai could be seen from space,[31] and the smoke and smog produced had engulfed the city for several days.[32]

It should be underlined that emissions from municipal solid wastes (MSW) are among the fastest-growing emission sources in India[33] due to increasing urbanization, rising incomes leading to more wastes, and absence of systematic waste collection, segregation and management. Reducing these emissions, especially methane which has around 30 times the global warming potential of carbon dioxide, is particularly important for India.

Refrigerant Gases : Another category of emissions increasingly emanating from Indian cities are groups of halogenated gases i.e. gases with chlorine, fluorine etc halogens as key components, such as chlorofluorocarbons (which include CFCs, hydrofluorocarbons or HFCs, hydrochloro-fluorocarbons or HCFCs, perfluorocarbons or PFCs) and sulphur hexafluoride. These gases are used mostly in refrigeration and air-conditioning, as well as in various industries such as semi-conductors, electronics, aluminium etc. After chlorofluorocarbons (CFCs) were found to be a threat to the ozone layer in the 1970s, significant efforts were made to eliminate CFCs from devices under the Montreal Protocol. However, the substituted gases, HFCs and HCFCs, while causing less harm to the ozone layer, have high global warming potential. Currently, aggressive steps are being taken all over the world, including India, to substitute these global warming inducing gases from air conditioners and refrigerators with more benign alternative, and chances of success appear bright since the industry has accepted these changes.

Evaporating Solvents : A less well known category of gases in our urban environment are those emanating from evaporation of organic chemicals that are being increasingly used mostly in urban areas.[34] A majority of these come from solvents in paints applied on buildings, vehicles, furniture and appliances, and also from many personal care products such as gels, nail paints, hair sprays and other personal care products. Dry-cleaning of clothes is also done with organic solvents (predominantly perchloroethylene). Aerosol cans for paints, hair sprays, creams and anti-asthma inhalers also contained CFCs which were gradually banned under the Montreal Protocol to protect the ozone layer, but their substitutes too still contain volatile organic compounds (VOCs). All these volatiles have higher density than air, leading to their greater accumulation in layers of the atmosphere nearer to the ground posing greater danger to human health and the local environment, contributing to smog, and also to atmospheric greenhouse gas concentrations.[35]

These compounds react significantly with other gases such as oxygen, ozone and nitrogen oxides (NOx), and trigger different chemical reactions in air. Reaction between nitrogen oxides and gases from VOCs also leads to production of ozone which is a greenhouse gas in the lower troposphere and, as mentioned earlier, also reduces capacity of plants to utilize carbon dioxide.[36]

Mineral Dust : Dust is a natural part of the atmosphere, which rises from many sites on the earth's surface and spreads over much wider regions due to winds, air circulation, temperature differentials and other weather phenomena. While this has been happening routinely over the centuries, accelerated developmental activities are causing much larger generation and re-distribution of dust as observed in recent decades.[37]

Penetration of farming into arid regions, desertification and land-use changes for urbanization, all expose top layers of soil and generate increasing quantities of loose dust which is then transported by winds. Recent studies have shown that dust has a surprising level of impact on global warming and climate change. For instance, increasing deposits of dust in the Himalayas and on other snow peaks causes substantial increase in snow-melt rates, exposing bare rocks and increasing reflective and radiative heat, besides exacerbating drought conditions. Transmission of dust-borne pathogens has also increased with increasing dust storms which have been noted in many parts of the world. Greater amounts of dust in the atmosphere also prevent sunlight from penetrating the atmosphere, affecting the climate both positively and negatively.

Cities and urbanization, particularly in India, contribute high amounts of atmospheric dust due to construction activities, vehicular movement and unpaved surfaces, besides ambient dust. Delhi has an annual average dustfall of 35 $g/m^2/yr$ with some of the sites showing figures as high as 168 $g/m^2/yr$.[38] For comparison, residential areas adjacent to Jharia coal mines in Jharkhand have an average dustfall of 116.6 $g/m^2/yr$.[39]

Dust affects the urban environment especially air pollution, to which it is a major contributor. Dust particles also provide convenient hosts for water vapour and other gases to bind, contributing to smog and lowering sunlight on the surface with all manner of effects. Many construction projects, an important characteristic of modern development, are not well planned or executed, leading to transportation of dust-laden materials over long distances, further adding to ambient dust, additional combustion of fossil fuels, and construction materials lying in the open ready to be carried away by winds. Urban dust may also include abraded or broken down particles from anthropogenic materials such as plastics, composites, electronic materials, paints, cements etc.

Pathways Ahead

As we have seen, causative factors and mechanisms linking them to climate change are numerous. While some general solutions do exist, a fixed "to-do" list would not suffice for addressing the problem in different geographical regions. Alternatives are needed in several areas: sanitation, construction techniques, paints, heating and cooling systems, and many more. It is important to realize that the need is not just to stop the use of certain chemicals or equipment, but also to assess the potential impacts of alternatives being explored. The case of CFCs is an important learning instance, when only one of the environmental impacts of the gas was considered, namely impact on ozone layer, while no-one looked at the climate change impact of alternatives.

Two important aspects make this complex task feasible. One possibility is to seek plurality of alternatives by promoting different innovations. Secondly, many of these aspects are inter-connected as lifestyle issues. For example, re-conceptualizing solid waste management may also require alternative methods of how food materials are purchased, stored and cooked. A relook at construction techniques and materials may also require re-conceptualizing urban spaces. Sustainable architecture using local materials provides possibilities for a much larger variety of building designs than are usually seen in cities today.

Many of the changes sought do not merely require technological innovations, but also economic and societal changes. Therefore, diversity of pathways and constant innovations at individual and systemic levels can provide the much needed climate change resilience. In case of sanitation, many waterless or low-water consuming sanitation systems are being developed and implemented in several parts of the world.[40]

The complex journey of finding alternatives to causative agents of climate change may not be necessarily painful. If seen from systemic perspectives with inherent inter-dependencies, and with a willingness to innovate lifestyles, this social transition towards tackling climate change can be a joyful one with many pleasant surprises. ❐

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